NIST and Engineering Laboratory Update

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Director
Engineering Laboratory
National Institute of Standards and Technology

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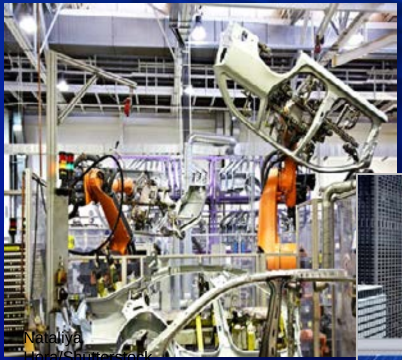

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Outline

- NIST Leadership Update
- Engineering Laboratory Strategic Goals
- Highlights of Program Accomplishments

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Engineering Laboratory Strategic Goals

- Smart Manufacturing, Construction, and Cyber-Physical Systems ← **Smart Grid**

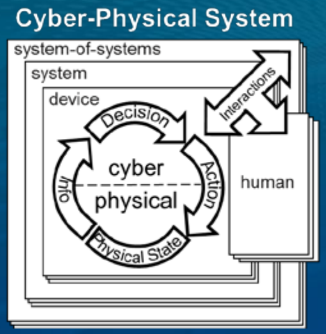
- Sustainable and Energy-Efficient Manufacturing, Materials, and Infrastructure ← **Building Integration Into the grid**

- Disaster-Resilient Buildings, Infrastructure, and Communities

Energy infrastructure and resilience

Cyber Physical Systems

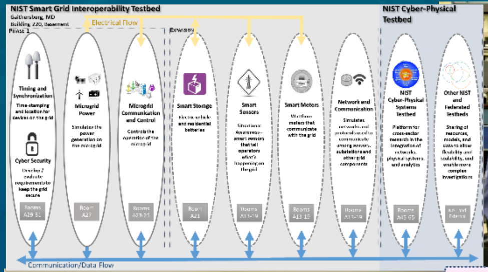
- **CPS Framework**
  - CPS Framework v. 1.0 published; open source tools for framework use.
- **CPS Testbed**
  - Architecture for reconfigurable, all-domain, mixed hardware/virtual components use; Conceptual design complete, initial construction 2016.
- **Global City Teams Challenge 2016**
  - To demonstrate replicable, standards-based CPS/Internet of Things solutions; 60+ teams 3 continents; June 2016 "Expo" in Austin, TX.
- **IoT-Enabled Smart (IES) City Framework**
  - NIST leading working group w/ 6 international partners; identifying harmonizing architecture principles, held U.S. and European launch events.

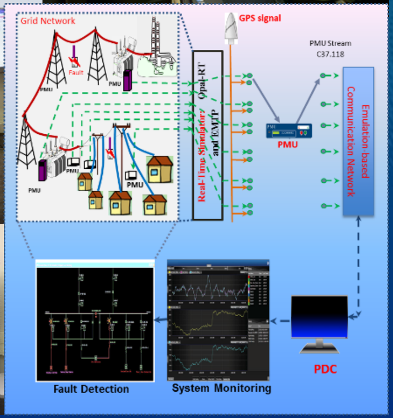


Smart Grid

- **Smart Grid Test Bed**
  Initial operations phase – first experiments include grid sensors, microgrid controls and cyber/timing
- **New Smart Grid Interoperability Panel (SGIP) Cooperative Agreement**
- **NIST Transactive Energy Challenge**

  7 teams participating, goal is to improve understanding of TE and to advance modeling and simulation capabilities (w/Embedded Intelligence in Buildings program)





NIST TRANSACTIVE ENERGY CHALLENGE
Modeling and Simulation for Grid Challenges

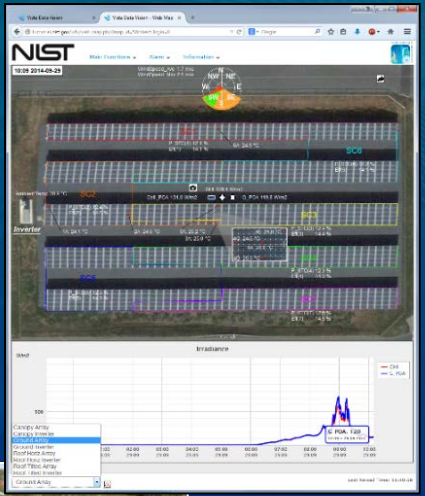
Embedded Intelligence in Buildings

- New standard approved by **ASHRAE and NEMA for Building to Grid Integration** using the Facility Smart Grid Information Model
- **HVAC Fault Detection Tool Deployed for Field Testing** - The Modular FDD-Expert Assistant. Sparks Dynamics CRADA partner.
- ASHRAE Guideline 0.2-2015, *Commissioning Process for Existing Building Systems and Assemblies* published

ASHRAE
NEMA
FSGIM
Facility Smart Grid Information Model
SPC 201P

Net-Zero Energy, High Performance Buildings

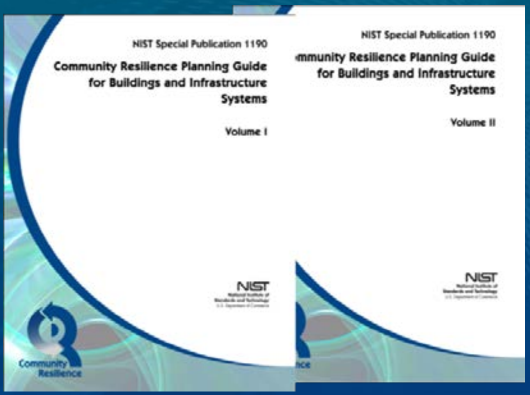
- **Photovoltaic Testbeds**
  - Completed 1-year period of data collection on NIST PV installations
  - Made available a collated data set for PV modeling community

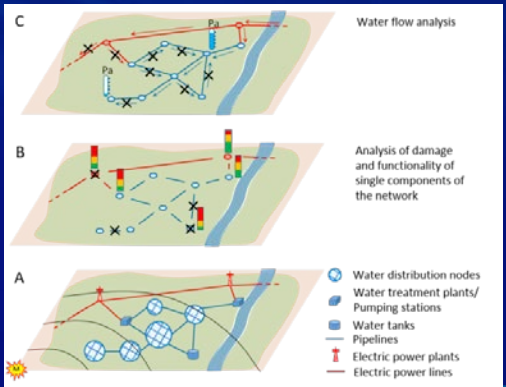


- **Net-Zero Energy Residential Test Facility**
  - Completed 2nd year test period with modified operational controls
  - Generated 18 % more energy than consumed
  - Demonstrated low indoor contaminant levels due to low-emitting materials
  - Launched new test phase with short-term tests on various equipment configurations

Community Resilience Program

- **Key Publications**
  - *Community Resilience Planning Guide for Buildings and Infrastructure Systems* (Oct 2015) – over 2000 downloads to date.
  - *Community Resilience Economic Decision Guide for Buildings and Infrastructure Systems* (Dec 2015).
  - *Critical Assessment of Existing Methodologies for Measuring or Representing Community Resilience of Social and Physical Systems* (Dec 2015)
  - *A Conceptual Framework for Assessing Resilience at the Community Scale* (Jan 2016)
- **Launched *Community Resilience Panel*** Nov 2015 – over 350 registered Panel members to date.
- Developing probabilistic damage and service models of buildings, water, power, & transportation systems in collaboration with CoE.





Smart Grid Community Loses One of its Leaders, Erich Gunther (1958-2016)

The smart grid community was deeply sadden by the untimely death of one of its pioneers, Erich Gunther. Erich was an exceptional talent, collaborator, and dear friend to many NIST staff. Many of us, both on the NIST Smart Grid team and in the Community Resilience Program, had the great privilege of working closely with Erich in recent years. Erich brought a rare combination of intelligence and passion—of head and heart—to his work, his hobbies, and, most of all, to the many communities he touched. We offer our deepest condolences to his family, his friends, and his co-workers at EnerNex.


Thank You

Smart Grid Program Overview

July 13, 2016

Avi Gopstein avi.gopstein@nist.gov
Smart Grid Program Manager
Smart Grid and Cyber-Physical Systems Program Office
National Institute of Standards and Technology
U.S. Department of Commerce

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

engineering laboratory

Smart Grid Program

Program Manager: Avi Gopstein
Associate Program Manager: Dave Wollman

FY16 Budget Allocation*:

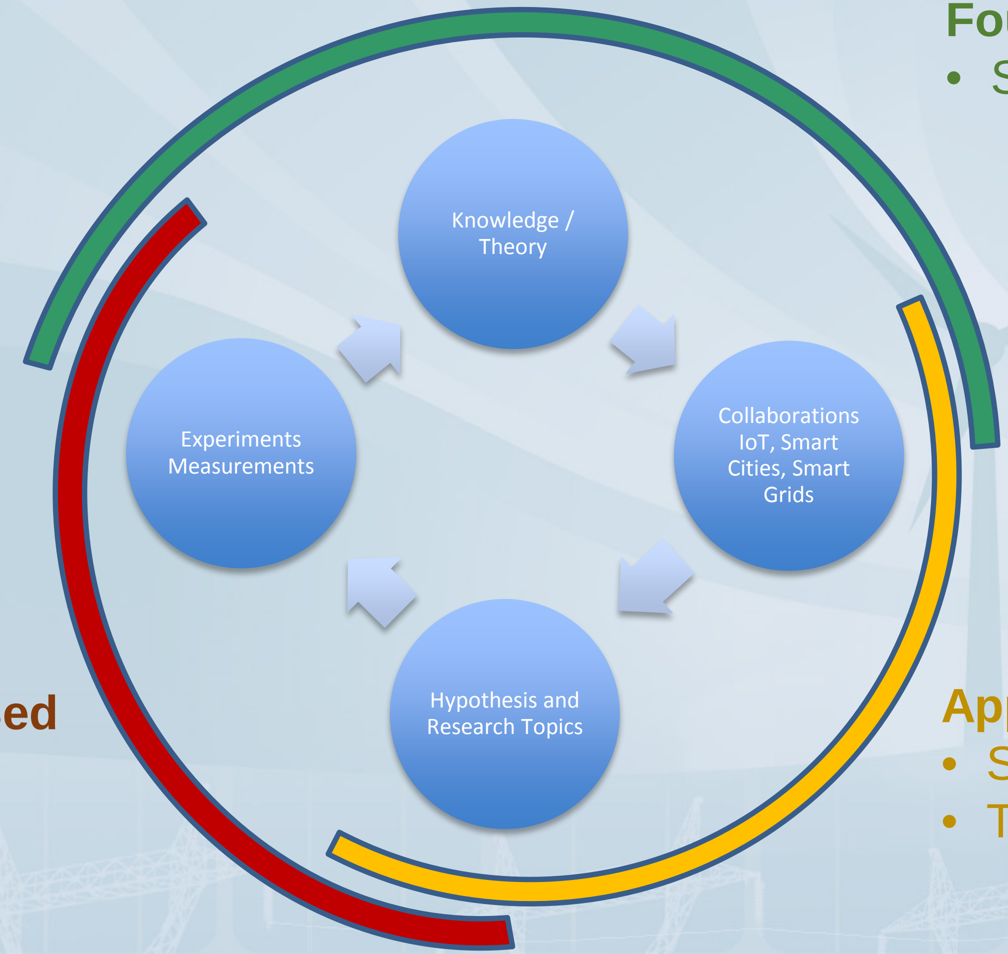
Program:	*$4.23 M*
SGIP:	*$1.35 M*
Transfer to ITL, PML, CTL:	*$3.22 M*
Total:	**$8.79 M**

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

*** Note: Does not include SG Exploratory Project**

SG Program

Foundations
- SG Framework



Experiment/Test Bed
- SG Research
- SG Test Bed

Applications
- SG Coordination
- TE Challenge

Smart Grid research motivations

Key factors

- The future of the grid is uncertain
- Interoperability enables communication, aggregation and optimization across multiple actors
- Technical innovation is expanding markets
- New technology + expanding and overlapping markets = disruptive opportunity
- Grid as platform, services provided by and between new groups

Issues SGP is addressing

- Smart Grid system performance
- Transmission and distribution operations
- Distributed energy resources and microgrids
- Coordination across industry, research, and governance

Smart Grid Program strategic themes

- Strategic coordination
  - Common research projects for common issues
  - External engagement

- Scientific context
  - Measurands gain value only when context is applied and actions are taken.
  - Precision vs. usefulness
  - Rigorous treatment of economic issues

- System
  - New markets, new actors, new opportunities
  - Devolution of control requires greater transparency, accountability, and trustworthiness
  - Interoperability without fragility
  - Trickle down impacts of grid as platform architectures

Smart Grid Program Overview

- Research
  - Monitoring and control
  - Cybersecurity
  - Communications & timing
- Experimental facilities
  - Smart grid testbed
  - Testbed integration
- External Engagement
  - Standards development
  - Smart Grid Interoperability Panel
  - Transactive Energy Challenge (TE Challenge)

Research: Monitoring & Control

- Key Research projects:
  - Wide-area Monitoring and Control of Smart Grid
  - Power Conditioning Systems for Renewables, Storage, and Microgrids
  - Smart Grid Communications Networks
  - Building Integration with Smart Grid

- Successes:
  - Conducted interoperability test of 8 commercial PMUs, drafted NISTIR on baseline performance, and developed draft PMU interoperability test specifications
  - Developed virtual PMU for simulation
  - Discovered that circuit topology, and even sensor placement, can drive instability in physical measurement and impact observability.
  - Laboratory demonstration of fault detection and location algorithm

- Plans:
  - Develop measurement requirements for optimization and control applications, particularly for distribution optimization including microgrids
  - Develop, deploy and test hardware-in-the-loop simulator for 61850 based protection and control applications
  - Develop system modeling and simulation techniques to support evaluation of future architectures
  - Expand a visualization framework for an interactive real-time display of network operation

Research: Cybersecurity

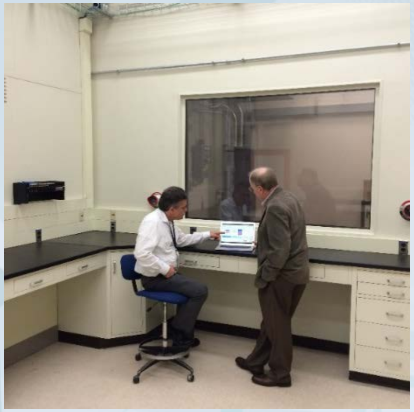
- Key Research projects:
  - Cybersecurity for Smart Grid Systems
- Successes:
  - Co-developed with Computer Security Division, inf-TESLA, a multicast delayed authentication for streaming sensor data in electric power systems.
  - Developed cybersecurity requirements for various smart grid projects and products, including:
    - OpenFMB
    - SGIP Priority Action Plans
    - IEEE 1588 standard on time synchronization
- Plans:
  - Thorough stability assessment of a multicast delayed authentication protocol for timed efficient stream loss-tolerant authentication (*inf*-TESLA)
  - Engage with NARUC to implementation of cybersecurity guidelines by utility regulators
  - Assessment of cybersecurity best practices for nested network architectures

Research: Communications & Timing

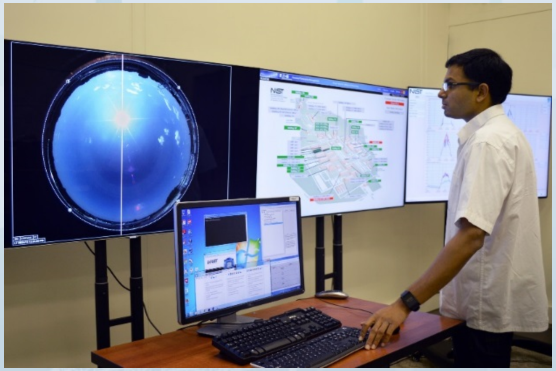
- Key Research Projects:
  - Precision Timing for Smart Grid Systems
  - Smart Grid Communication Networks
- Successes:
  - Developed a theoretical approach to analyzing timing uncertainty.
  - Developed a linguistic framework for expressing temporal assurance.
  - Publication: Integrated Distributed Energy Resources and Storage Devices in Smart Grid: Modeling, Analysis, and Evaluation.
- Plans:
  - Utilize SG testbed to evaluate multiple communication network architectures and develop suitable routing protocols for distributed generation grid systems.
  - Develop and evaluate sensor technologies and state estimation algorithms with respect to sensitivity to timing uncertainties.
  - Expand timing testbed infrastructure for calibrating source time signal quality.
  - Publish NIST report on timing requirements for smart grid
  - Characterize 5G networking technologies and architectures for smart implementation of distributed applications

Experimental Facilities: Smart Grid Testbed

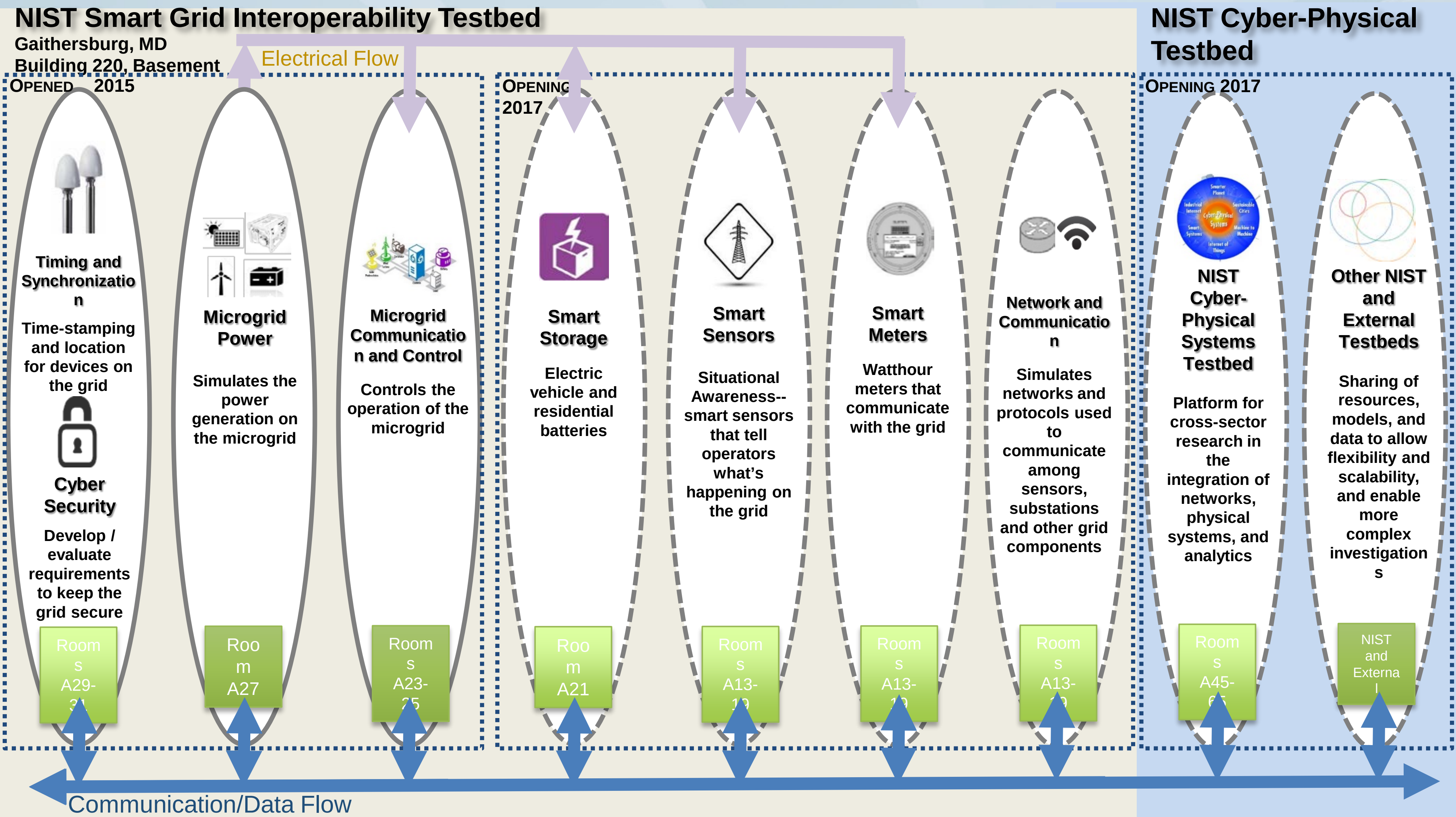
- **Smart Grid Interoperability Test Bed operational**
  - Microgrid Facilities (AC and DC Grid Emulators, Smart Inverters) (220: A27 and A25)
  - Timing and Synchronization / Cybersecurity (GPS Antenna, IEEE 1588 clocks, Network Switches) (220:A29-31)
  - Interoperability test of smart sensors for Smart Grid (220:A23)
  - Multi-OU effort: EL, PML, ITL, CTL
  - Testbed safety monitoring and daily operational coordination



- **Plans for at least three significant successes**
  - Standards and Test for Microgrid Interconnection Equipment and Controllers (SGIP PAP 24) – *Hefner*
  - Develop Interoperability Test Methods for Smart Sensors (e.g. MUs) for smart grids based upon IEC standards - *FitzPatrick*
  - The Use of Synchrophasor Measurements in Electric Power Systems Protection and Control Applications - *Gharavi, Anand*



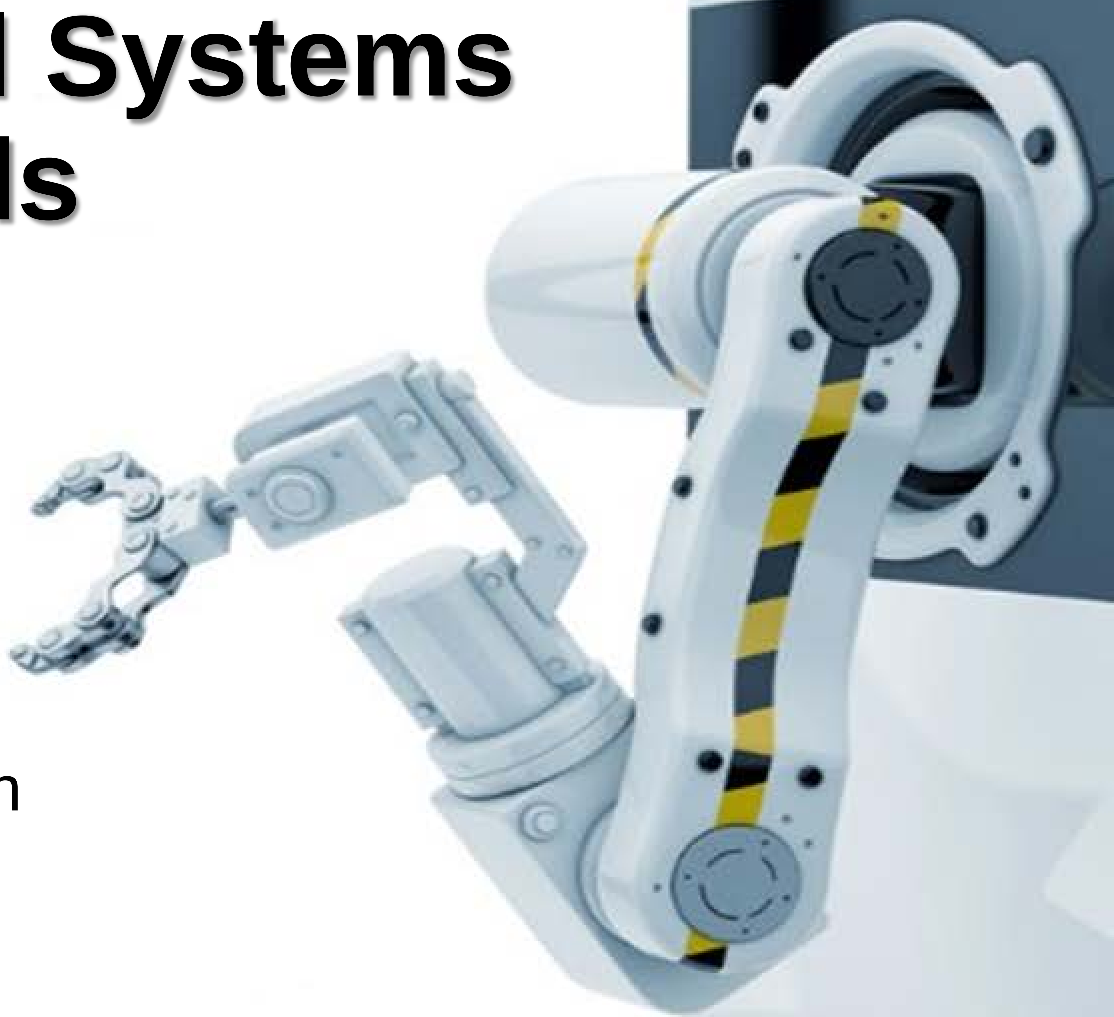
Experimental Facilities: Testbed Integration



Challenges ahead

- What do changing business models mean for:
  - Interoperability requirements?
  - Measurement science?
- What gaps exist between theory and practice?
  - What is NIST's most effective role in bridging?
- Are future grid architectures adequately understood?
  - If yes, what are the key issues that need standardization?
  - If not, what laboratory research can advance this understanding?
- What types of sensors and measurements are necessary for operation and optimization of distribution grids?
- How granular must distribution sector observability be for operations, economics?
  - How do requirements change as a function of user?
  - How do we address gap between ideal and minimally acceptable?

Smart Grid and Cyber-Physical Systems Testbeds



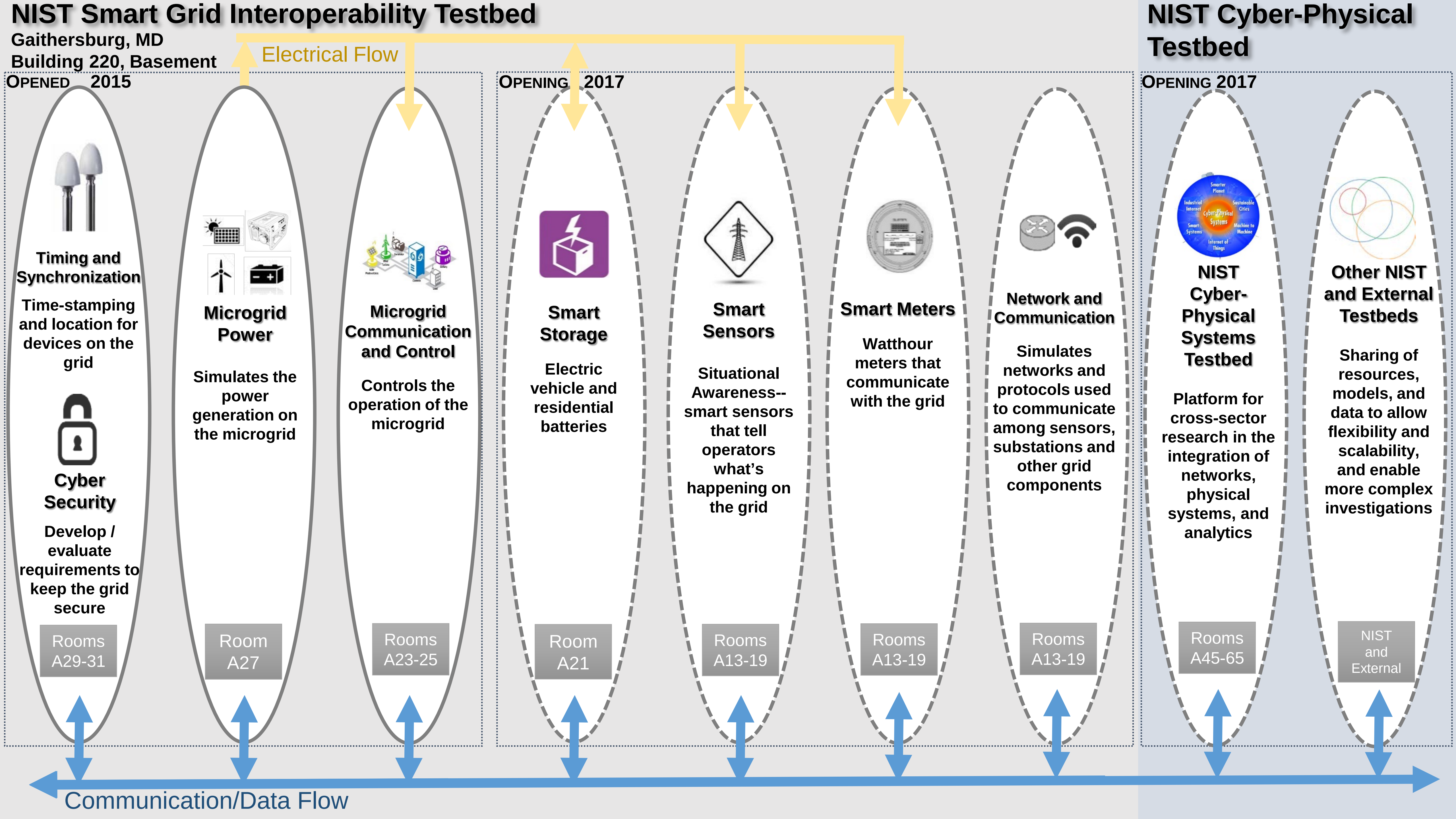
July 13, 2016

Paul Boynton

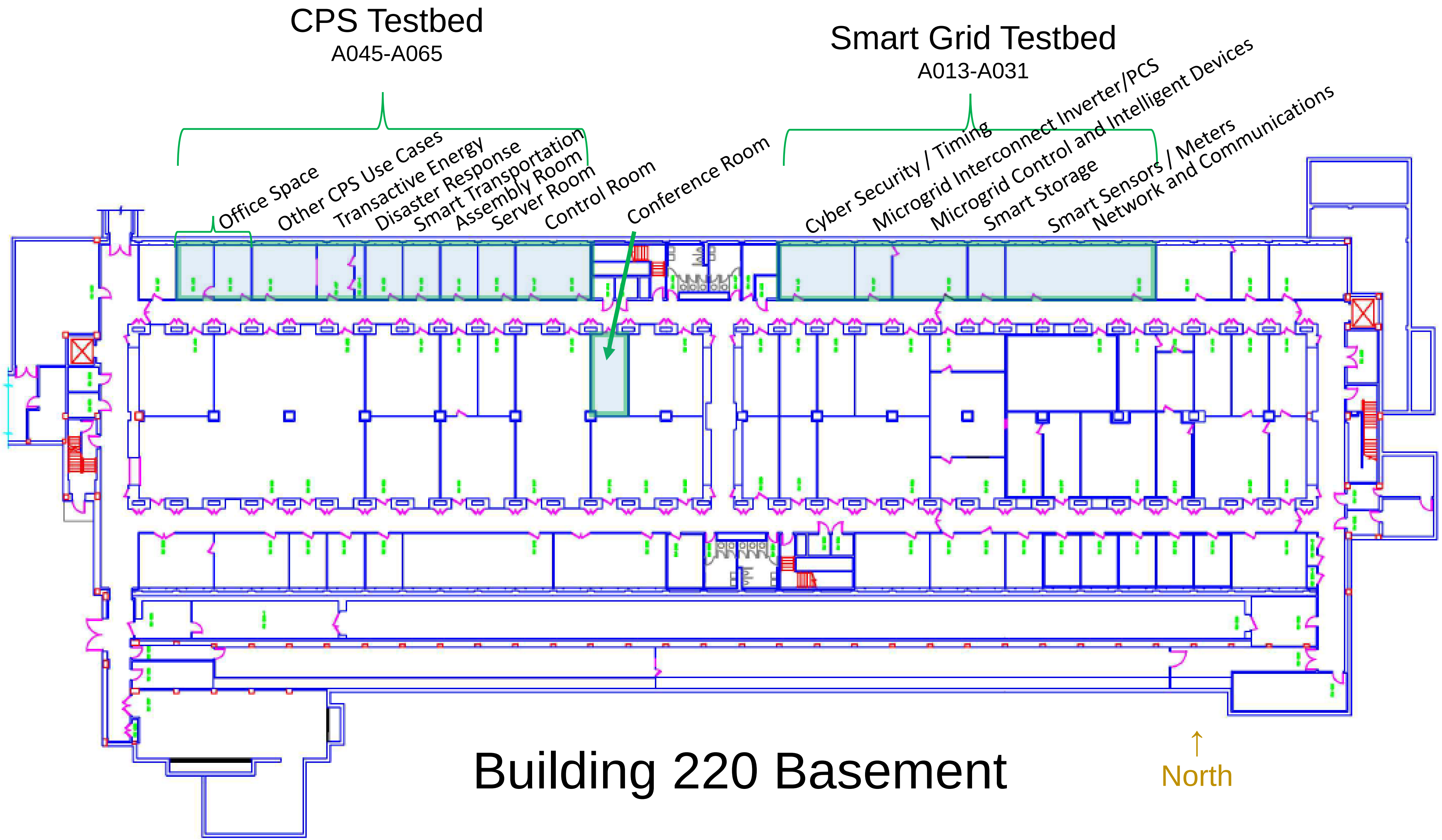
NIST Smart Grid Testbed

- **Objectives**
  - To provide the foundational infrastructure for smart grid interoperability research
  - To accelerate the development of smart grid interoperability standards by addressing the measurement needs of smart grid industry
  - To develop and participate in a community of testbeds
    - Workshops held in March 2014 and February 2015
    - Identified gaps and challenges to testbeds
    - Singled out key design principles

- **Scope**
  - Designed to be composable, collaborative, and coordinated
  - Perform measurements of system-level, end-to-end device level smart grid performance and interoperability
  - Measure and characterize key components, standards, and protocols of smart grid systems and devices
  - At present, focus research on microgrids


NIST Smart Grid Interoperability Testbed
Gaithersburg, MD
Building 220, Basement
Electrical Flow
NIST Cyber-Physical Testbed
OPENED 2015
OPENING 2017
OPENING 2017
Timing and Synchronization
Time-stamping and location for devices on the grid
Cyber Security
Develop / evaluate requirements to keep the grid secure
Rooms A29-31
Microgrid Power
Simulates the power generation on the microgrid
Room A27
Microgrid Communication and Control
Controls the operation of the microgrid
Rooms A23-25
Smart Storage
Electric vehicle and residential batteries
Room A21
Smart Sensors
Situational Awareness--smart sensors that tell operators what's happening on the grid
Rooms A13-19
Smart Meters
Watthour meters that communicate with the grid
Rooms A13-19
Network and Communication
Simulates networks and protocols used to communicate among sensors, substations and other grid components
Rooms A13-19
NIST Cyber-Physical Systems Testbed
Platform for cross-sector research in the integration of networks, physical systems, and analytics
Rooms A45-65
Other NIST and External Testbeds
Sharing of resources, models, and data to allow flexibility and scalability, and enable more complex investigations
NIST and External
Communication/Data Flow

NIST Smart Grid/CPS Testbed Locations



NIST Smart Grid Testbed

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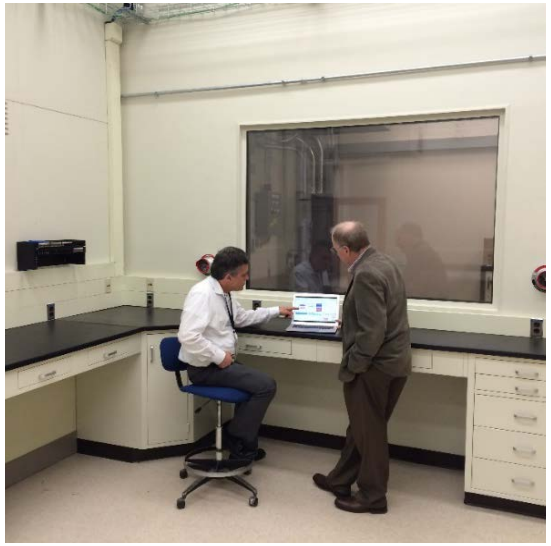

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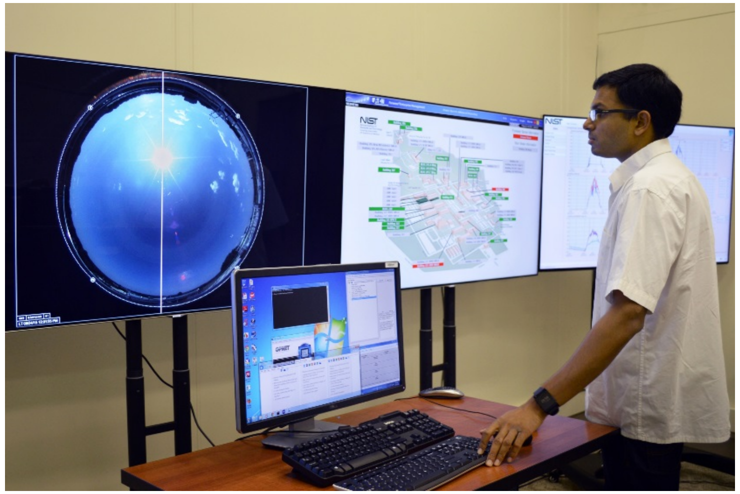
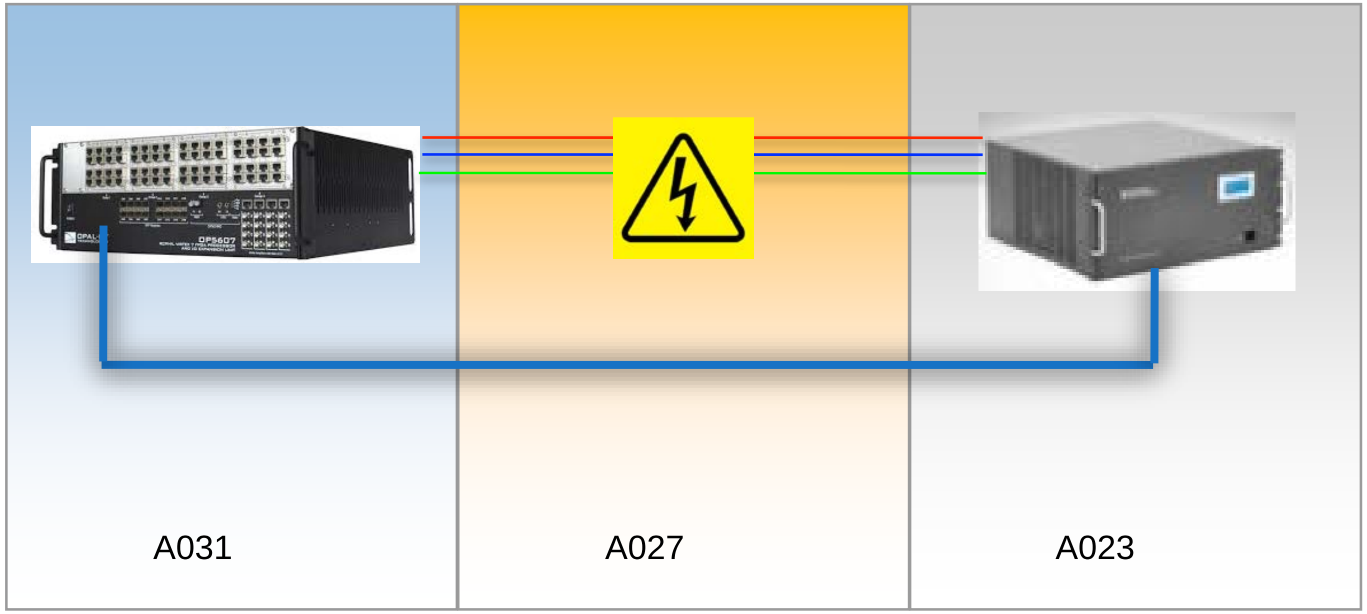
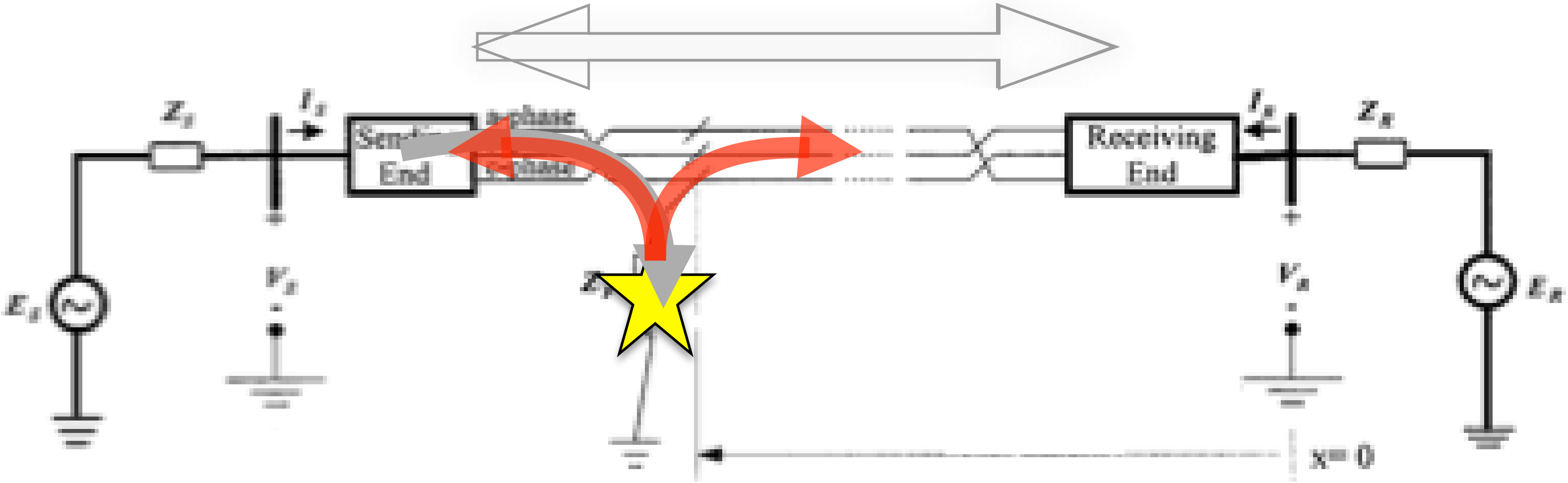


Shared testbed resources

- Simulate frequency instabilities in a microgrid - evaluate sensor performance.
- Develop a fault detection algorithm for microgrids -multi sensor fusion



EL Exploratory project



Projected Outcomes

- We are interested in extending and validating algorithms and methods *beyond software simulation*
- Using existing sensors in a hardware in the loop fashion would let us *extend calibration standards* to keep pace with algorithm development
- *Innovate on both ends:* sensor specifications for future applications, applications that better use sensor data

Why a Federated Testbed Architecture?

- What federation enables
  - Combine equipment that is unique or can't be collocated
  - Proprietary components can be exposed by designed experiment interfaces
  - Creates reusable components of experiments
  - Integration of models from multiple domains
  - *Our approach allows leveraging existing and disparate simulation tools and hardware in the loop and rapid experiment design and configuration*
- Experimental Use Cases Enabled by Federated Testbeds
  - Local Experiment
  - Cloud Hosted Simulations and Experiments
  - Hardware In The Loop
  - Collaboration w/Remote Federates at other Labs
  - Large Scale Experiments (10s, 100s, 1000s of federates)
  - +++ Combinations of above

CPS Test Bed: Federation of Experiments

Federated experiments allow components of experiments to be distributed locally, in clouds, and/or geographically dispersed.

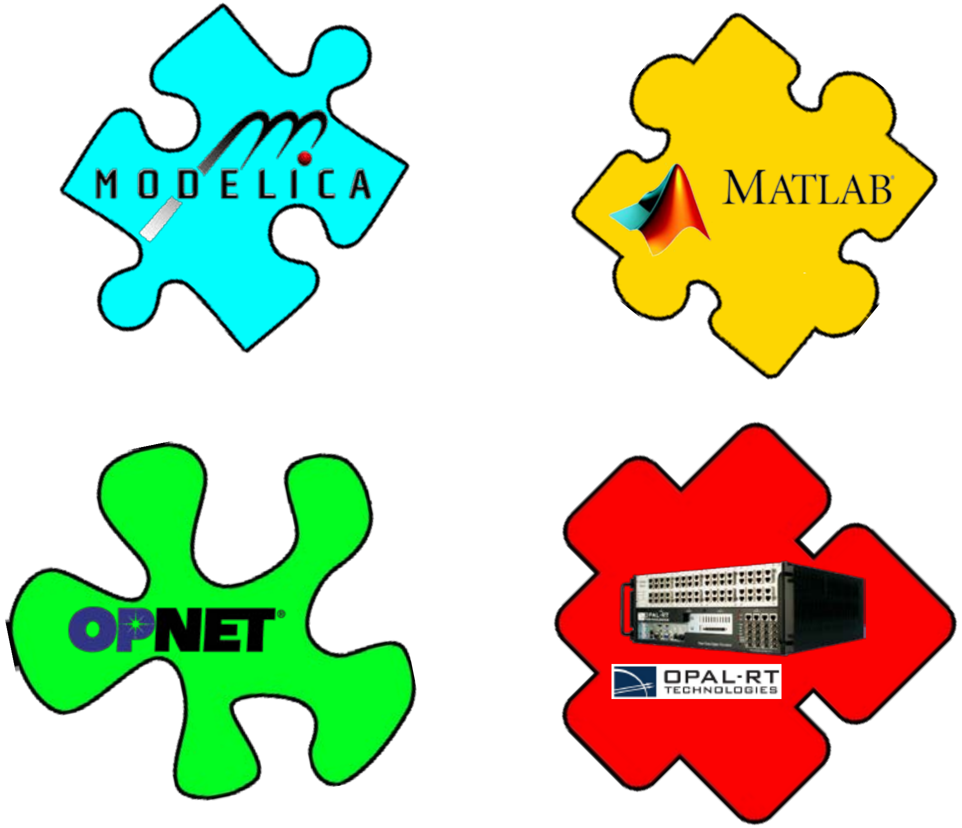
- A Federate is a component of an experiment. It could be a piece of equipment, a simulation model, or a permutation of multiples of both….
- Federates can be located anywhere and are identified by their description and network address.
- A Federation is a collection of Federates that can be part of an experiment.
- An Experiment is the description of the orchestration of a Federation to exercise the Federates and exchange of information among them.
- The Federation Manager is a specialized Federate that operates on the Experiment definition and the Federation to perform the actual experiment.

Universal CPS Experimental Facility (UCEF) Testbed

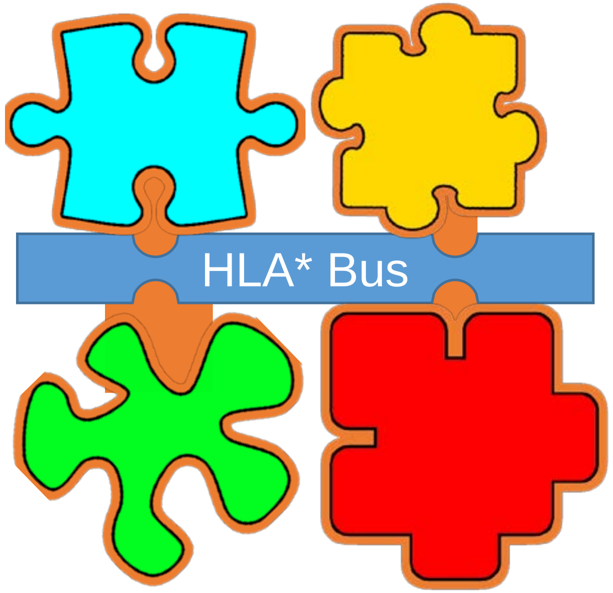
- UCEF as a Platform
  - Federated Testbed Architecture
  - Linux Virtual Machine Redistributable including federate and experiment design tools
  - Federates may be designed or pre-existing
- Key Features:
  - Lightly Wrapped (adapted) Simulators/Emulators
    - Light-wrapping of best of breed simulators/emulators such as Matlab/Simulink, Modelica, Opnet, Spice, Dymola, SUMO,….
  - Common experiment orchestration using HLA bus
    - IEEE 1516.1 Standard for Modeling and Simulation (M&S) High Level Architecture (HLA) -- Federate Interface Specification
    - Open Source Run Time Implementation of HLA – Portico
    - Experiment Orchestration Languages – Colored Petri Nets (CPN) and Courses of Action (COA)
  - Yields best practices for “communities of testbeds”

Federation Concept

Best of Breed heterogeneous Simulators/Emulators/HIL Testbeds

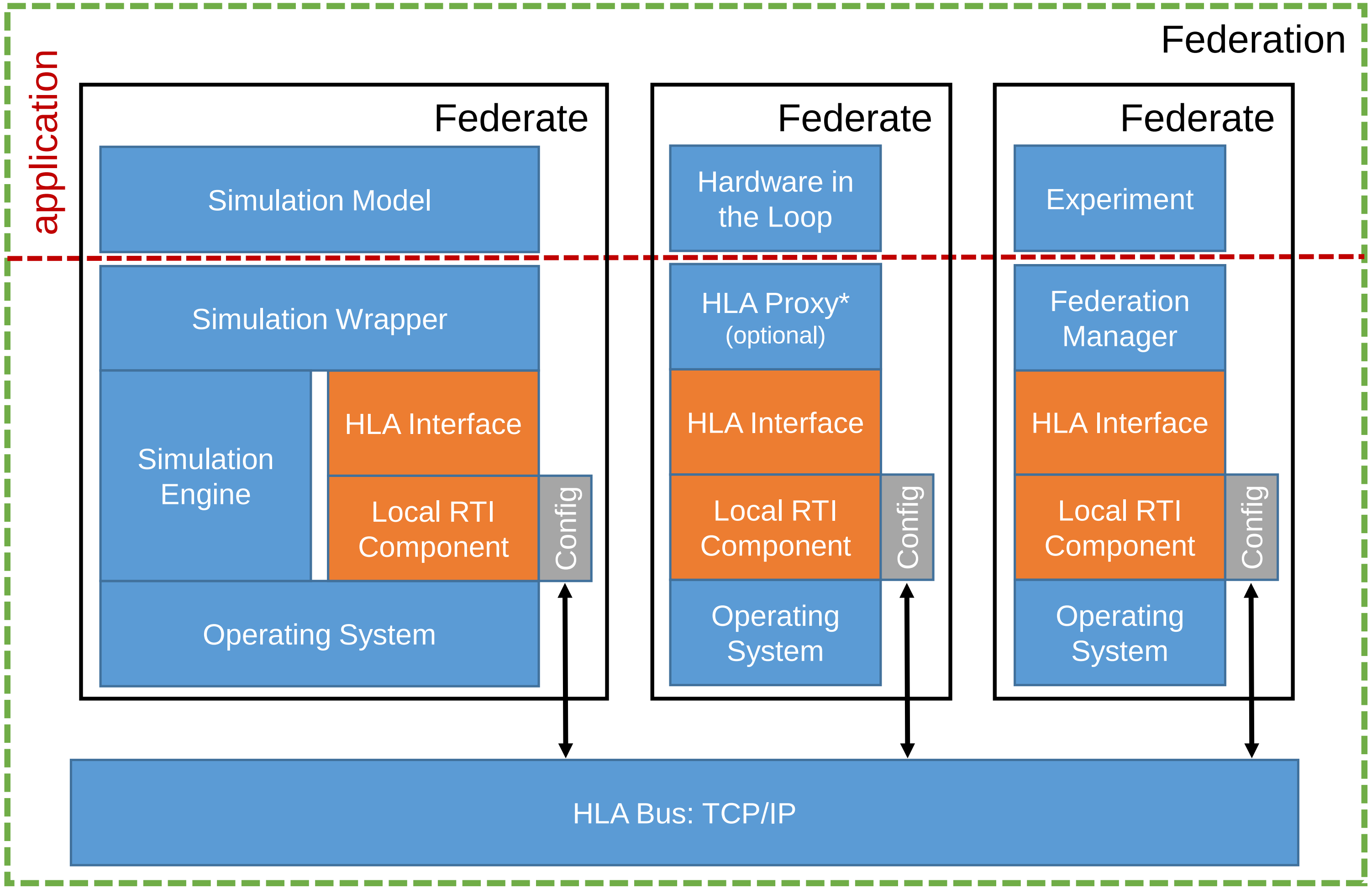


Light-Integration Wrappers + Common Experiment Orchestration Bus



*https://standards.ieee.org/findstds/standard/1516-2010.html

UCEF Federation Architecture



* proxy needed if target CPS function cannot support HLA stack

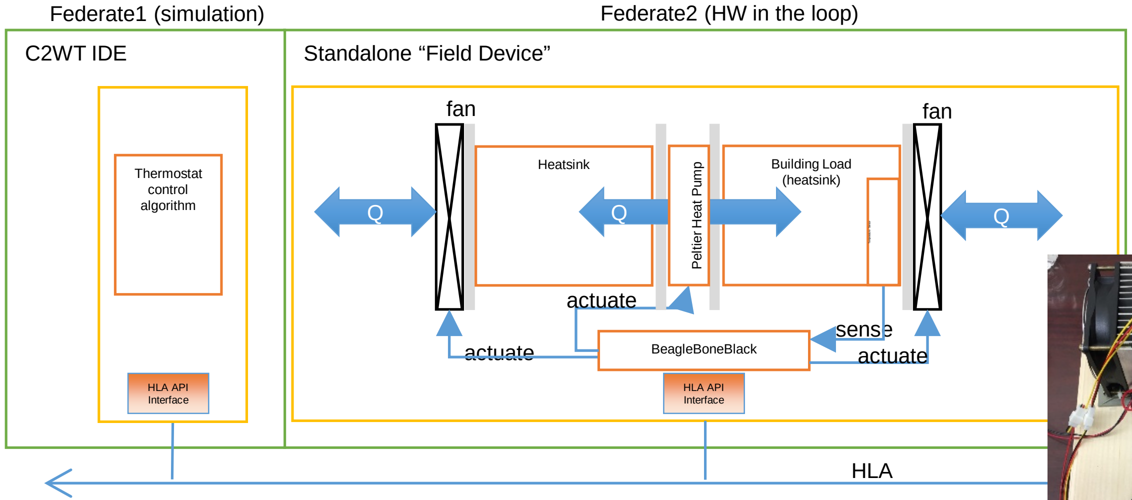
Example: Initial Federated Experiments

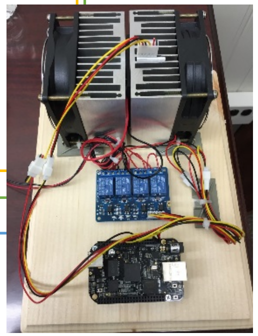
Use Case: Use a software-implemented Thermostat to control a hardware in the loop "HVAC System" emulation

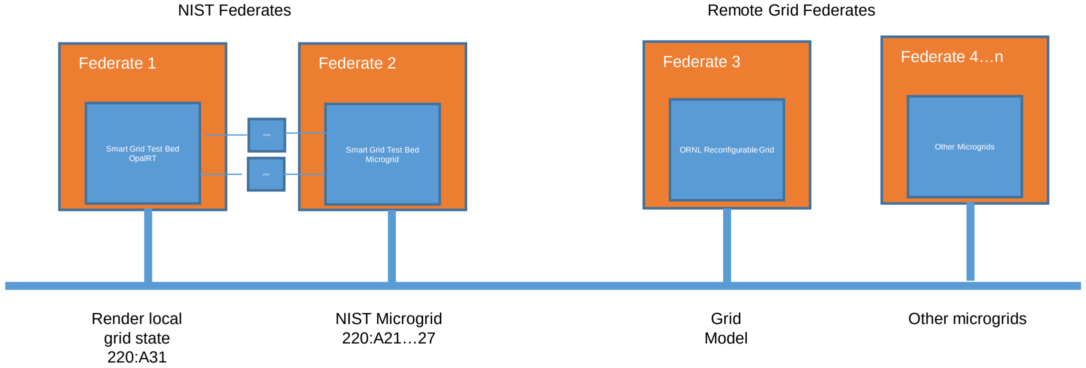
Use Case: Use a physical emulation of a grid segment at one lab, along with microgrid simulations at other labs to analyze behavior of a grid of microgrids

Use Case: Transactive Energy Challenge for comparative analysis of energy markets

Use Case: Autonomous Vehicle experiments with remote hardware and software implemented to protect proprietary components





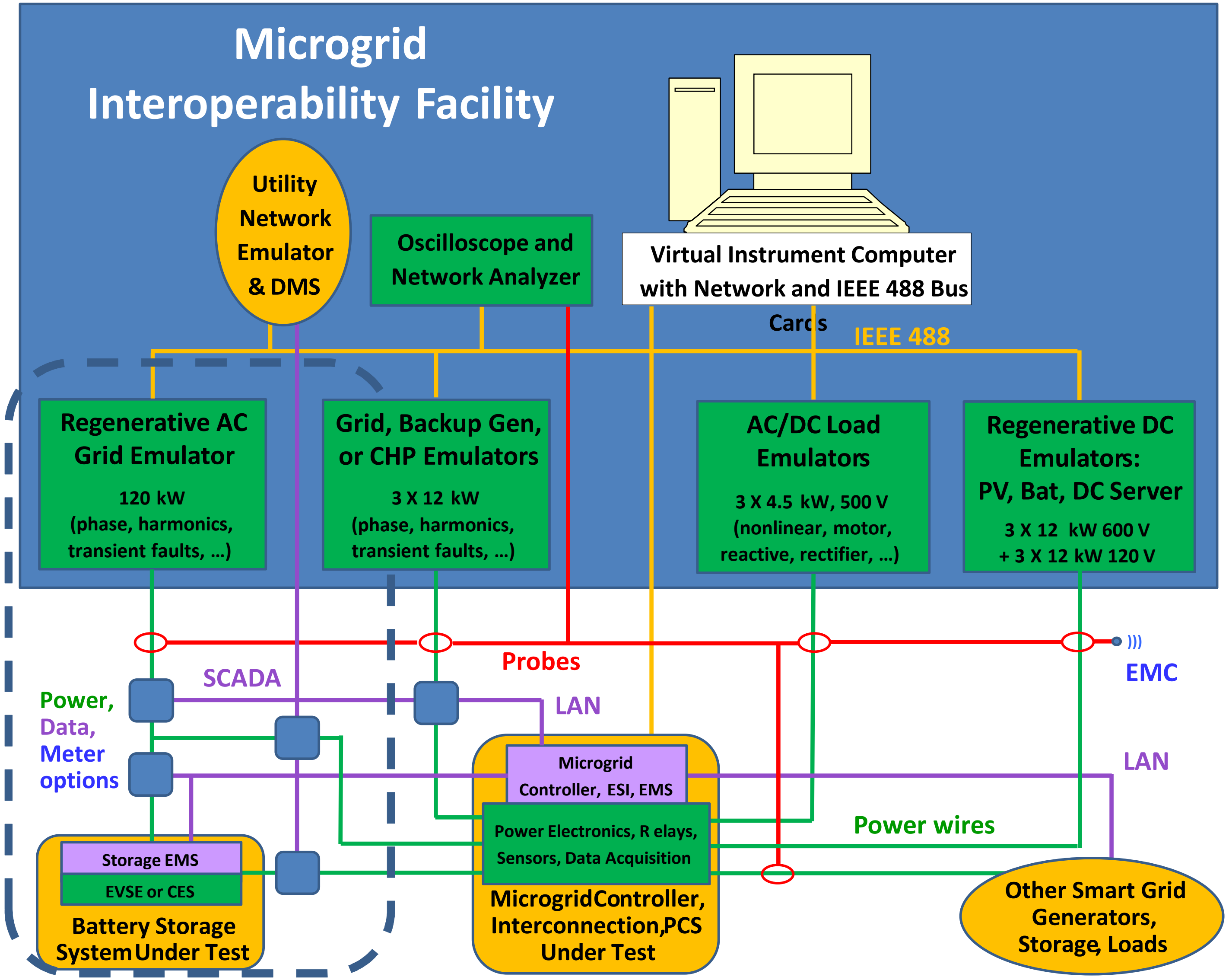


Questions?

Backup Slides

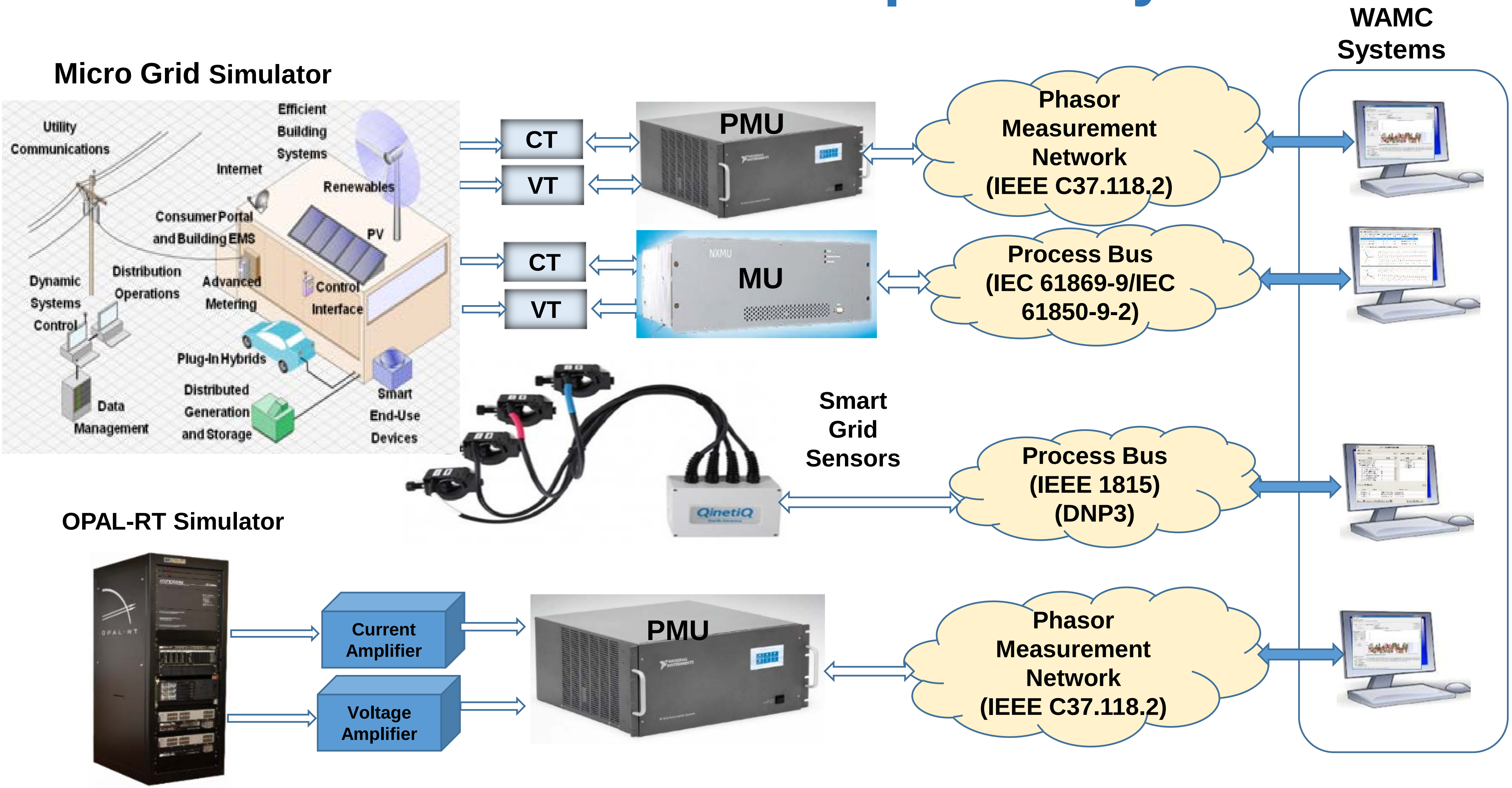
Microgrid Interoperability Facility

- Addresses metrology needed for interoperability of advanced microgrid devices and systems
- Extensible to all aspects of multilevel distributed control
- Focused on unique NIST mission of Smart Grid interoperability and leverages SGIP activities
- Incorporates elements of many of the projects in the NIST smart grid portfolio
- Coordinated with other agencies and industry programs
- Aligned with partner test bed architectures to enable interchangeability of devices between test beds
- Support standard development (IEEE 1547 series, IEEE p2030.7, IEEE p2030.8)



Contact: Al Hefner: allen.hefner@nist.gov

Smart Sensors Interoperability Testbed

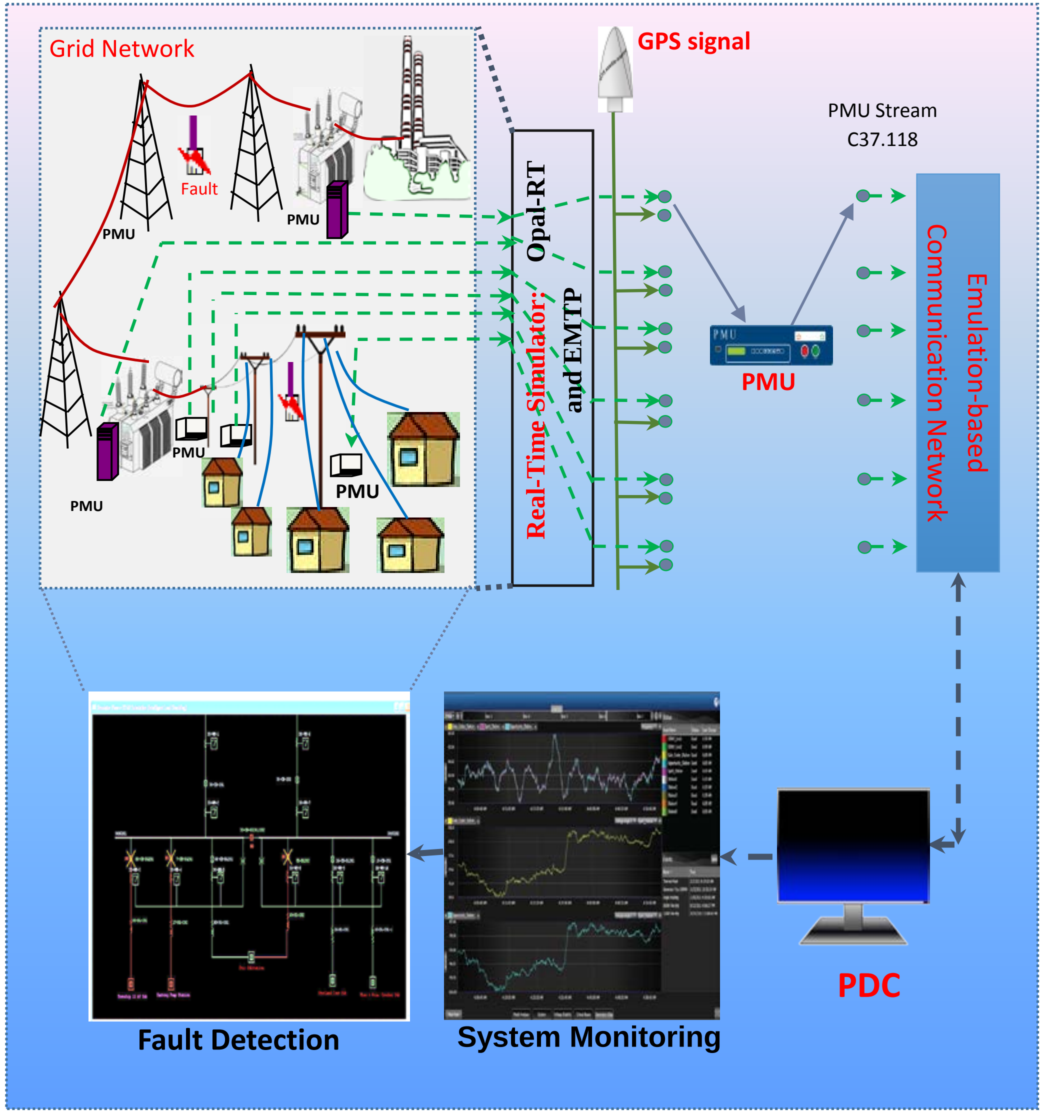


**Contact: Gerald J FitzPatrick:
gerald.fitzpatrick@nist.gov**

FY16 Measurements in Power Systems Protection and Control Project

Description/Objective

- Advanced measurement and control are key enablers for a safe, reliable, cost-effective and sustainable power system.
- This project will leverage the new NIST Smart Grid Interoperability Testbed to build a hardware-in-the-loop simulation environment for understanding key contributors to measurement and control uncertainty in next-generation power systems. The research simulation framework can also be used to develop novel state estimation and control algorithms.



Organization

- Staff from EL, ITL and PML will jointly participate in this effort using unique qualifications and experience gained from ongoing smart grid programs.

Key Milestones

- Implement a real-time synchrophasor testbed that includes interfacing commercial PMU's
- Collect synchrophasor measurement data and conduct statistical analysis to validate the performance of developed system
- conduct tests to assess the accuracy of fault location algorithms

NIST Transactive Energy Challenge Update

David Holmberg
Engineering Laboratory
July 13, 2016

Summary

- The Smart Grid FAC helped identify TE as a subject area that would benefit from NIST action (2014). We have given regular updates.
- NIST continues to advance TE-related standards in international SDOs. We also have TE-related research in NIST laboratories.
- The NIST TE Challenge has been the focus of our TE effort. We are currently midway through Phase I.
- The TE Challenge received good visibility at the TE Systems Conference in Portland in May.
- We have faced challenges to advance simulation tools and co-simulation platform(s)—the main goal. To gain momentum, we have launched a Tiger Team effort this summer focused on a common co-simulation architecture (working with PNNL/ Vanderbilt/ CMU) that will enable Phase II. We are coordinating well with DOE.

TE Challenge development premise

- For TE to become a reality, industry and regulators must be comfortable that they understand how TE will work and what the implications will be.
- Modeling and simulation are critical to achieve the necessary understanding.
- Various parties have developed simulation capabilities that can form pieces and parts of what is needed.
- A challenge can identify existing parts, stimulate collaborations, and create a synergy that will advance the state of the art.

TE Challenge Goals

1. Advance simulation tools and co-simulation platforms for TE evaluations.
2. Demonstrate how different TE approaches may be used to improve reliability and efficiency of the grid for various scenarios.
3. Develop a set of reference scenarios to serve as reference points for TE evaluations.
4. Build up the TE community.
5. Work toward real-world implementations.
6. Provide a “stage” for participants to showcase their work.

→ Deliver value to utilities, regulators and policy makers in under-standing, testing, an applying TE to meet today’s grid challenges.

Timeline

- TE Challenge Preparatory Workshop, March 2015—demonstrated TE community agreement on TE Challenge vision
  - Identified grid challenges and gaps in modeling and simulation for TE
- Phase I Launch, September 2015 for vision setting and team formation. Assembled 5 teams.
- Interim Meeting, December 2015 for coordination and team building. Added two new teams.
- Phase I reports at the May 2016 TE Systems Conference (Portland, OR)
- TE Co-simulation Tiger Team meeting, June 23, 2016
  - PNNL, CMU, Vanderbilt, NIST working on co-simulation architecture
- Phase I Capstone at NIST, Sep 20-21 2016
- Phase II Launch, winter 2017

TE Challenge Phase I Teams

1

TE Regulatory and Business Models

Goals:

- Define fundamental TE business and regulatory models
- Characterize/define interfaces among the participants (physical/financial)
- Identify legislative and regulatory features applicable to each model

Deliverables: White Paper

Leader: EEI, with Bluewave Resources, ICFI, CGI, PNNL, NIST, TeMix, OATI

2

Transactive ADR

openADR Transactive

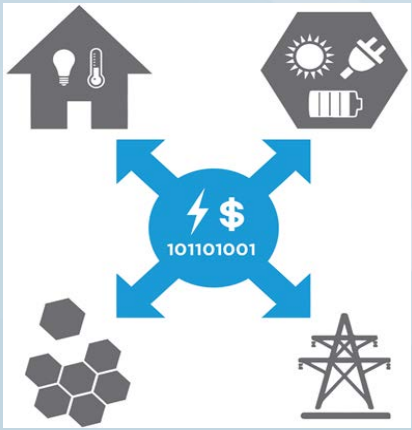
Goal: Advance TE in OpenADR Alliance, leveraging established DR member alliance to create an industry solution for TE.

Deliverables: Transactive profile

Leader: OpenADR Alliance

TE Microgrids Demonstration

3



Goal: Develop microgrid demonstration and simulations to show potential for energy management within and between microgrids using one or more TE approaches.

Deliverables: Demonstration results, TE approach documentation, simulation results

Leader: Iteros, with Energy Mashup Lab, General Microgrids, Tata Consultancy, MIT, ABB, Navigant, Businovation, Dartmouth, OATI

PowerMatcher IoT

4

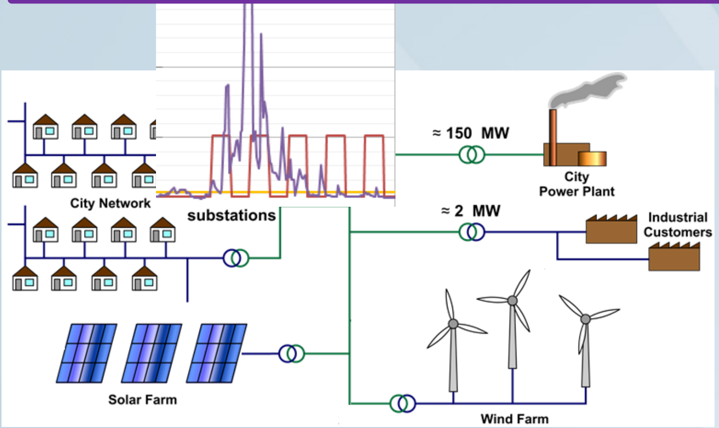
PowerMatcherSuite
Transactive Smart Energy

Goal: Demonstrate the benefits to the US electric grid of a market approach using PowerMatcher.

Deliverables: Demonstration providing loads and DER assembled into a virtual network implementing PowerMatcher bid interactions over XMPP.

Leader: MaCT USA

5 Reference Grid and Scenarios

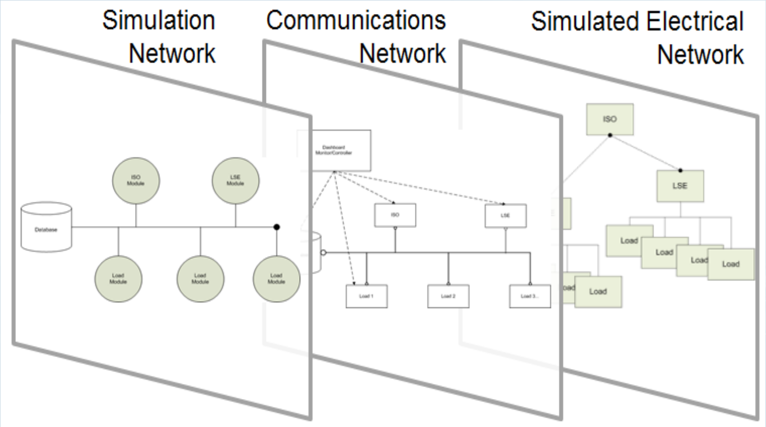


Goal: Develop reference grid designs, scenarios and interoperability requirements to support testing of TE approaches using different simulation tools while producing comparable results.

Deliverables: Reference Grid models for a small set of scenarios.

Leader: NEMA

6 Co-simulation Platform



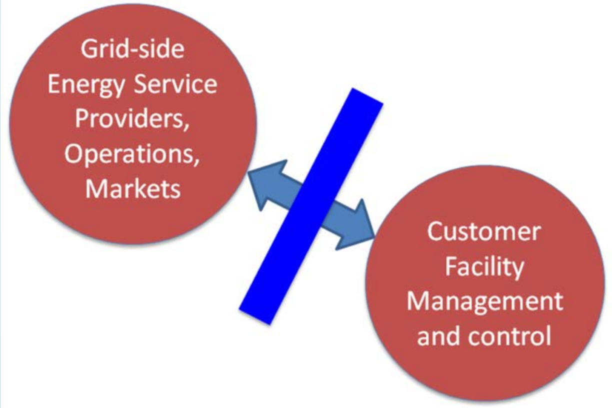
Goal: Create an "Open Platform" (extensible and customizable) for integrating and coordinating across a diverse suite of modeling and simulation tools, and conduct integrated experiments.

Deliverables: Open platform design and guidelines for use.

Leader: CMU/Vanderbilt

7

Common Transactive Services



Goal: Align simulations with real TE message exchanges by finding common meanings across environments.

Deliverables: White paper

Leader: Energy Mashup Lab

Co-simulation architecture Tiger Team and 6/23 meeting at NIST

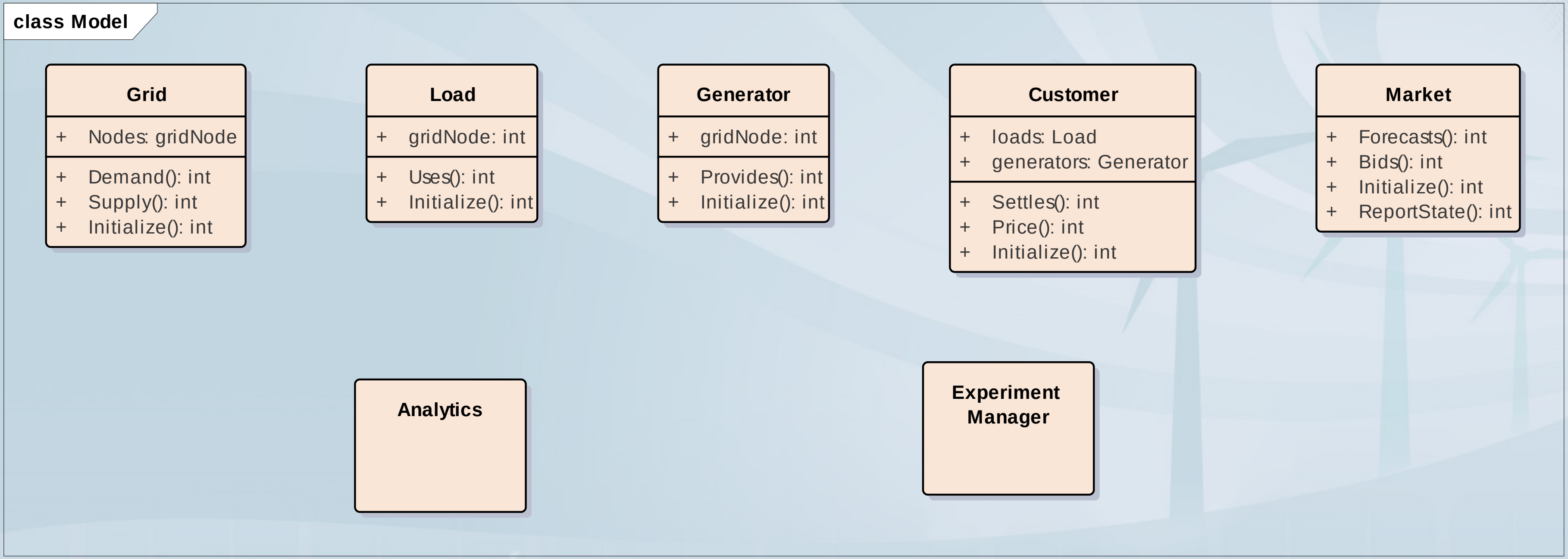
The problem: multiple independent simulation platforms, proprietary simulation tools, and no interoperability potential.

Tiger Team Goal: Accelerate agreement on a co-simulation framework in preparation for TE Challenge Phase II use.

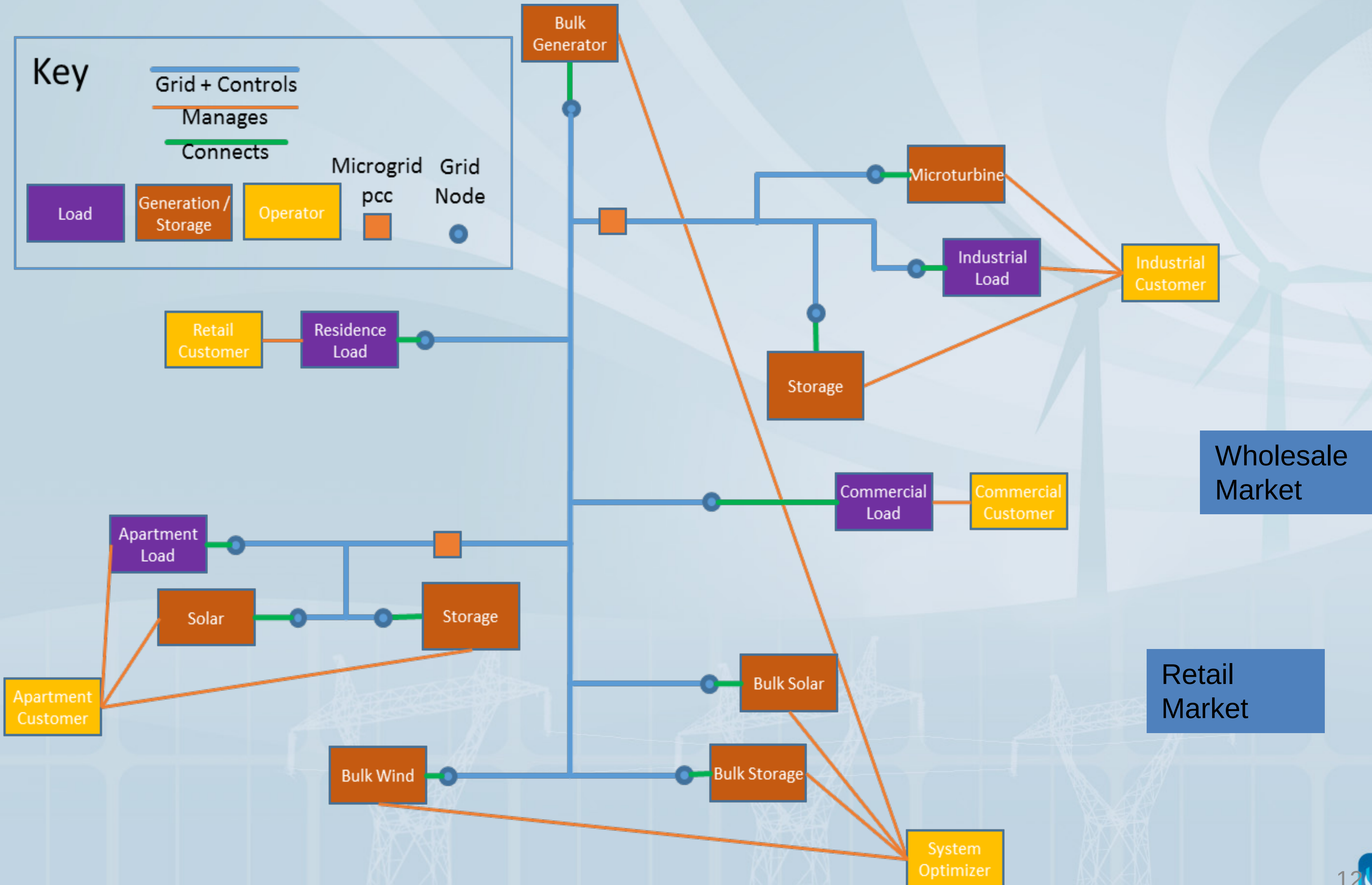
Purpose of the 6/23 Face-to-face with PNNL, Vanderbilt and CMU:

- Pursue agreement on a basic component architecture and begin developing details of component interfaces.
- Select the example grid design and scenario.
- Select metrics that we will ask teams to report.
- Build the foundation for Phase II, where team results can be contrasted and compared for a limited problem set, thus demonstrating the potential of a federated collection of simulation tools.

Potential Co-sim Model Components



Co-sim architecture high-level view



TE Use Case Scenarios

- TE Challenge team: *Reference Grid and Scenarios*
    - Khaled Masri, NEMA (Lead)
    - Warren Wang, Navigant
    - Steven Ray, CMU
    - Jason Veneman, MITRE
    - Rob Stewart, Pepco
    - Amro Farid, Dartmouth
- Six scenarios defined:
    - Scenario 1: Peak Heat Day & Energy Supply
    - Scenario 2: Wind Energy Balancing Reserves
    - Scenario 3*: High-Penetration PV and Voltage Control
    - Scenario 4: EVs on the Neighborhood Transformer
    - Scenario 5: Islanded Microgrid Energy Balancing
    - Scenario 6: System Constraint + Mandatory Curtailment

Continued work leading to Phase II

- Tiger Team architecture (components and interface definitions), scenarios, metrics—prepare draft report for September meeting
- Phase I teams complete work and present in September Phase I Capstone
- Fall—preparation of co-simulation testbed components for use by Phase II participants
- Promotion and invitation of new participants in the TE Challenge Phase II

TE Challenge Phase II

- Phase II Launch in winter 2017
  - Possible meeting collocated with DistribuTECH, 2017
- Phase II goals:
  - Advance simulation tools for TE and demonstrate performance of TE approaches to meet grid needs.
  - Use the Phase I work products to the greatest degree possible to drive interoperability and collective advance—reference scenarios, reference grids, performance metrics, and common co-simulation platform.
  - Make co-simulation platform publically available with repository of components.
  - Continue to add participants: universities, vendors, gov't labs
  - Work toward utility implementation trials
  - Continue to focus on delivering value to utilities and others looking to solve grid problems

Grid 3.0 Update

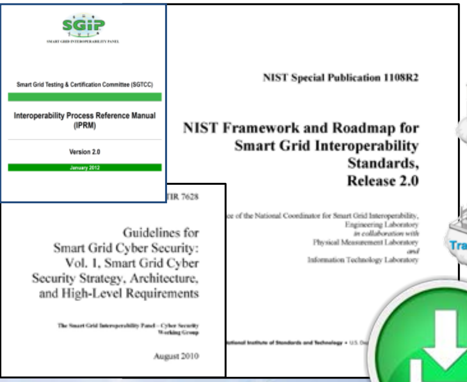
Dr. David Wollman – david.wollman@nist.gov

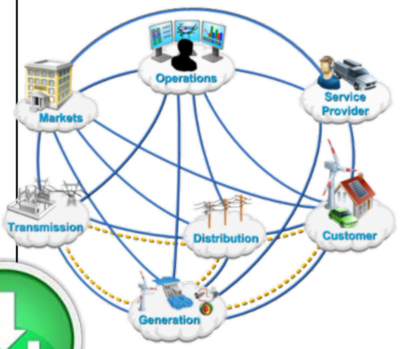
Deputy Director, Smart Grid and Cyber-Physical Systems Program Office, Engineering Laboratory

National Institute of Standards and Technology

Stakeholder Engagement in Smart Grid is Important

- Energy Independence and Security Act (2007)
  - NIST: responsibility to work with stakeholders to coordinate development of a consensus-based framework for smart grid interoperability standards: initial workshops, Smart Grid Interoperability Panel (SGIP), … SG R&D portfolio
  - DOE: numerous stakeholder engagement activities, ARRA projects, Nat'l Labs
  - EPRI, NEMA, GWAC, EEI, NRECA, APPA, IEEE, IEC, UCAIug, NAESB, Univ, …





NIST smart grid testbed(s)

Grid 3.0 Multi-Organization Collaboration

- What does “Grid 3.0” mean?
  - Grid 1.0: legacy grid (traditional grid, centralized generation/control)
  - Grid 2.0: smart grid (current state, new IT/intelligence+communications)
  - Grid 3.0: future grid (fully modernized grid; operations fundamentally different: flexible, resilient, highly-interactive, able to take advantage of new capabilities to meet evolving policy goals)
- What is the goal?
  - Promote coordination and collaboration among many organizations with smart grid interests to most efficiently identify/address critical issues and perform the research and development needed to achieve Grid 3.0.
- Formal or informal?
  - Informal: ad hoc collaboration to engage and organize interested stakeholders

Grid 3.0 Collaboration Partner Organizations

- Electric Power Research Institute (Don von Dollen)
- DOE (Chris Irwin)
- NIST (Dave Wollman, Avi Gopstein)
- Smart Grid Interoperability Panel (Sharon Allan)
- GridWise Architecture Council (Ron Melton – PNNL)
- NEMA (John Caskey)
- UCAIug, IEEE Smart Grid
- Edison Electric Institute
- Others (Utilities, Ron Cunningham, Ray Palmer, …)

Grid 3.0 Kickoff Workshop (March 2015)

- Host: NIST Gaithersburg,
  90+ participants, live webcast
- Workshop Topics:
  - Enabling new entrants and innovation
  - Impact of technology and flexible resources
  - Enhancing reliability and resiliency
  - Enabling new and evolving markets and business models
  - Architecting the change
  - Evolving industry structure

Grid 3.0 Multi-Organization Collaboration

- How?
  - Identify the critical issues that the industry is facing
  - Develop “future states” and prioritize initial roadmapping activities/workshops
  - Identify current status and gaps to reaching “future states”
  - Identify willing organizations to address gaps/critical issues and coordinate activities (build collective momentum/urgency)
- “Future States” – aspirational future statements articulating the vision for how a fully modernized grid will look/operate in 5-10 years with respect to an identified characteristic or attribute.
  - Not just technical issues such as interoperability or architecture, scope also includes policy, regulation and business models, and workforce and metrics

Grid 3.0 "Future States"

Group 1 – Policy, Regulation & Business Model

- [Industry shaped consensus … through a **collaborative process**.]
- A clearly defined set of **regulatory models** with a clear understanding of the jurisdictions of the state and federal regulators has been established
- Clear, sustainable **business models and value propositions** that allow the industry stakeholders to profitably support the needs of the economy have been established
- [Stakeholders have an **equal place at the table** …]
- [**Regional cooperation** and collaboration …]

Grid 3.0 "Future States"

Group 2 – Technical Development

- Provide a set of conceptual **architecture** models across the architecture domains which can be made available to any electric sector stakeholder as a starting point for sustainable businesses and processes
- Well defined points of **interoperability** characterized by agreed upon standards exist and are utilized by all electric sector stakeholders
- [Decision support environment … efficient use of **data** and knowledge ..]
- [Coordinated **reference designs** and documentation …]
- Well defined and clearly understood **privacy ecosystem** that both allows use of data to sustain the industry and provides for individual needs
- Well defined and clearly understood **proactive security** ecosystem that sustains the operational and business needs of all stakeholders

Grid 3.0 "Future States"

Group 3 – Workforce and Metrics

- Provide an environment that **retains and attracts** motivated individuals who thrive with continuous incremental education and skills improvement in an evolving industry
- Clearly defined and utilized **metrics** exist for electric system infrastructure (e.g. reliability, resiliency, quality, security, economics, customer-related and efficiency)

- …and we are adding one additional technical "Future State" on **communications** (in editing process)

Grid 3.0 Roadmapping – Deeper Dives

- With input from survey/stakeholders, the Grid3.0 leadership team prioritized three initial roadmap development workshops to identify gaps, actions, and organizations to address them … and we can additional future states over time.
- **Grid Architecture**
  - Convener: GridWise Architecture Council (GWAC)
  - Host: PNNL
  - Held: 2-3 Dec 2015, Richland, WA
- **Interoperability**
  - Convener: SGIP
  - Host: American Electric Power (AEP)
  - Held: 8-9 Dec 2015, Tulsa, OK
- **Communications**
  - Convener: EPRI (&DOE)
  - Host: Southern Cal Edison (SCE)
  - Held: 6-7 April 2016, Irwindale, CA

Grid 3.0 workshop: Grid Architecture

- **Future State:** We have a set of conceptual architecture models across the architecture domains which can be made available to any electric sector stakeholder as a starting point for sustainable businesses and processes

Issues

- Lack of a policy and regulatory framework to develop workable architectures within
- Lack of broad stakeholder understanding of the discipline of architecture, why it is needed, and how it is used
- Lack of a business case framework for developing architecture
- No clear repository for architectural artifacts, templates, data object, and supporting documents
- Limited collaborative development of broadly available architectural models and documentation
- Existing industry architectures tend to focus on automation and data aspects rather than the broader overall industry needs

Grid3.0 workshop: Interoperability

- Topic areas:
  - Making the Case for Interoperability – communicate value proposition
  - Implementing Interoperability – procurement best practices, stds. navigation tool (GE)
  - Testing and Certification – testing and certification ecosystem
  - Interoperability Development – tools and aids for standards development efforts
  - Interoperability Curricula – educational material on interoperability for new generation
- Follow-on discussion underway with SGIP Technical Committee
- Assessment of synergistic activities, may propose new additions to the technical activity list

Grid 3.0 workshop: Grid Communications

Preliminary discussion (wordsmithing improvements anticipated during editing process)

- Communications networks will provide borderless, secure communications utility-to-utility and utility-to-third party
- Communication networks will be conformant to national/international standards with well defined profiles and minimal optionality to minimize integration challenges, and the ability to interoperate in a multi-vendor environment
- Communication networks will be secure where edge devices support the modern suite of security protocols so the network doesn't have to proxy security for edge devices
- Communication networks will have WiFi like compatibility and capability to consistently join utility devices to utility networks
- Comprehensive planning and simulation tools exist that support the efficient design and deployment of advanced multi-technology networks
- Communications networks will be adaptable with intelligent provisioning of applications and services supporting QoS and defined non-functional requirements specific to the application

Next Steps – Grid 3.0

- Stay tuned for Grid3.0 workshop reports, follow up roadmapping, …
- To participate: http://www.smartgridsharepoint.org/grid3pt0/
- NIST: opportunity to use results to inform SG Framework R4 …

NIST SG Advisory Committee group discussion tomorrow morning on topics of "Grid3.0 Drivers for Change and Architectures for Interoperability"

sgip

Advancing Grid Modernization

NIST Smart Grid Advisory Committee Update
July 2016

SGIP Update

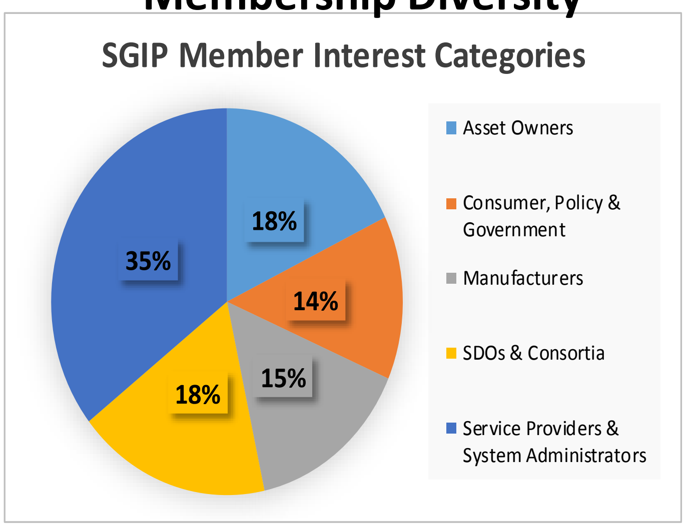
- Organization Update
- Technical Areas of Focus
- Technical Program Accomplishments
- Milestones Reached
- SGIP Annual Conference – November 2016

SGIP Business Focus and Outreach

2016 Focus Areas:

- Distributed Energy Resources - Launched Grid Management Working Group
- Energy IoT - OpenFMB focus on Microgrids as well as frameworks for home/bldg automation
- Cybersecurity - Guide for utilities implementing programs
- Standards & Interoperability – Existing working groups plus GMLC projects. Navigation tool for standards.
- Orange Button - Lowering the cost of solar

Membership Diversity



2016 Stakeholder Engagement (ytd)

- 13% growth in Twitter Followers
- 16% growth in LinkedIn Followers
- 7 Newsletters Delivered, 4 Webinars Held
- 11 Press Releases Issued
- 2 Videos
- 6 Placed Articles
- 13 Face-to-Face Stakeholder Meetings

2016 Revenue Plan

Revenue Source	Amount
Membership	$633,000
NIST Funding	$911,000
DOE Orange Button	$230,803
Total Revenue 2016	$1,774,803

Percentage of Staff Salaries Paid by Revenue Source

	NIST	DOE	Membership
Sharon Allan	18%	15%	67%
Aaron Smallwood	55%	20%	25%
Gabrielle Puccio	24%	25%	51%
Mohammad Rahman	80%	10%	10%

Distributed Energy Resources

- SGIP launched the Grid Management Working Group in 2016
- Mission is to bring together Grid Operations Technology and Business leaders from utilities to discuss key operational concepts/capabilities and architecture principles relating to future Grid Control & Operational technologies needed to manage a more complex grid due to the rapid rise of DERs
- Group will open up to broader stakeholders next year. Utilities will present their combined thoughts to the broader stakeholders later this year to open up the dialogue and discussion
- Present participants include: SCE, PG&E, ComEd, Pepco, PSE&G, SoCo, Ameren, DTE, Duke, BcHydro, London Hydro, FPL, Avista, National Grid

Technical Area of Focus: Cybersecurity

- Cybersecurity White Papers and Articles:
  - NIST Cybersecurity Framework Implementation Case Study
  - "Sharing Can Help Utilities Fight Cyber Threats." March/April issue of Electric Energy T&D Magazine
  - SGIP White Paper: Implementing Cybersecurity Frameworks: Utility Lessons Learned

- Focus on OpenFMB™ Cybersecurity
  - Enhancing OpenFMB™ Cybersecurity with additional use case functionality:
    - Configuration Management
    - Certificate Management

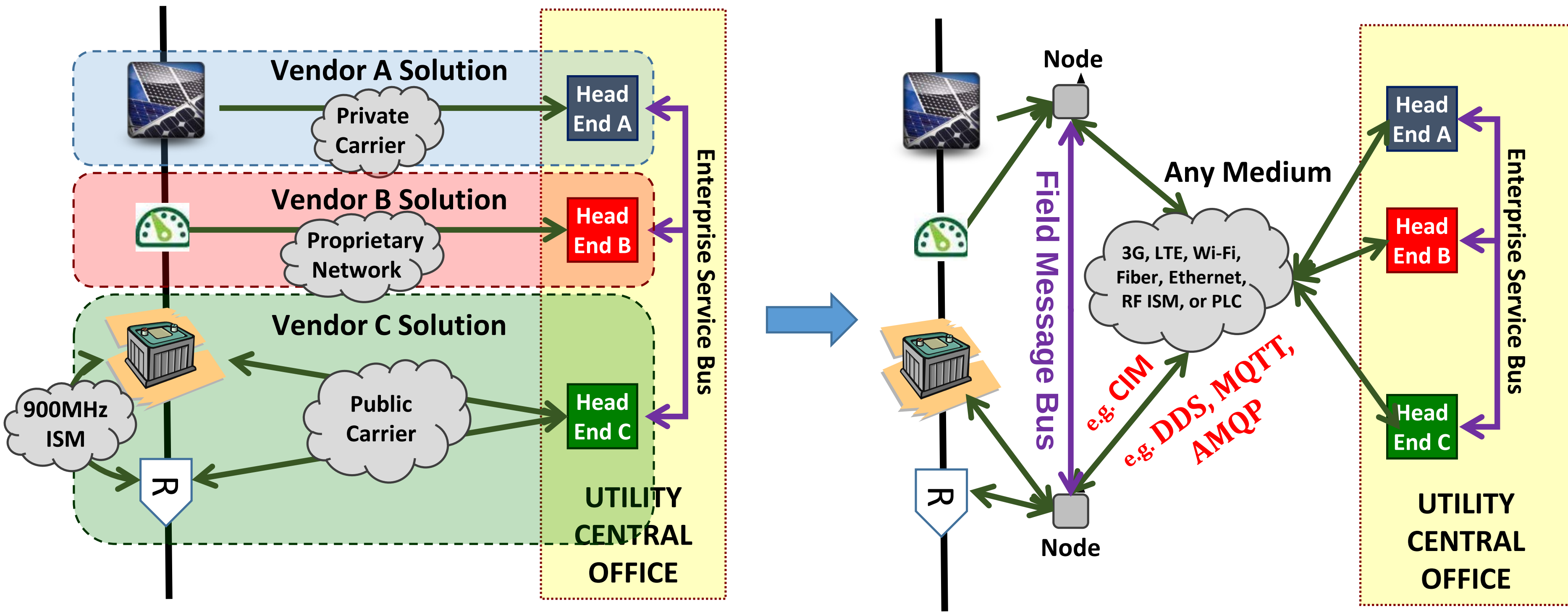
- SGIP Smart Grid Cybersecurity Committee (SGCC) priorities;
  - SGCC OpenFMB™ Cybersecurity Task Force
  - Forming Cyber/Physical Security Resiliency Task Force
  - Performing SGIP Catalog of Standards reviews

- Facilitating a utility driven workgroup that is developing an implementation case study that shares real world lessons learned from implementing the NIST Cybersecurity Framework

OpenFMB™: The Catalyst for Interoperability

- Open Field Message Bus (OpenFMB™) is a reference architecture and framework for distributed intelligence
- Leverages existing standards to federate data between field devices and harmonize them with centralized systems
  - IEC's Common Information Model (CIM) for semantic data model
  - Internet of Things (IoT) publish/subscribe protocols
    - DDS: Data Distribution Service
    - MQTT: Message Queue Telemetry Transport
    - AMQP: Advanced Message Queue Protocol
- NAESB OpenFMB™ Model Business Practices standard ratified in March
- 2016 OpenFMB™ focus areas include:
  - Cybersecurity
  - Increased base of utility participation
  - Pursuing utility driven use cases
  - Create an online community of interest and publish OpenFMB™ software with installation and configuration instructions

OpenFMB™: Enhancing Grid Edge Integration



Key Observations:

1. Single-Purpose Functions
2. Proprietary & Silo'ed systems
3. Latent , Error-prone Data
4. OT/IT/Telecom Disconnected
5. **No Field Interoperability!**

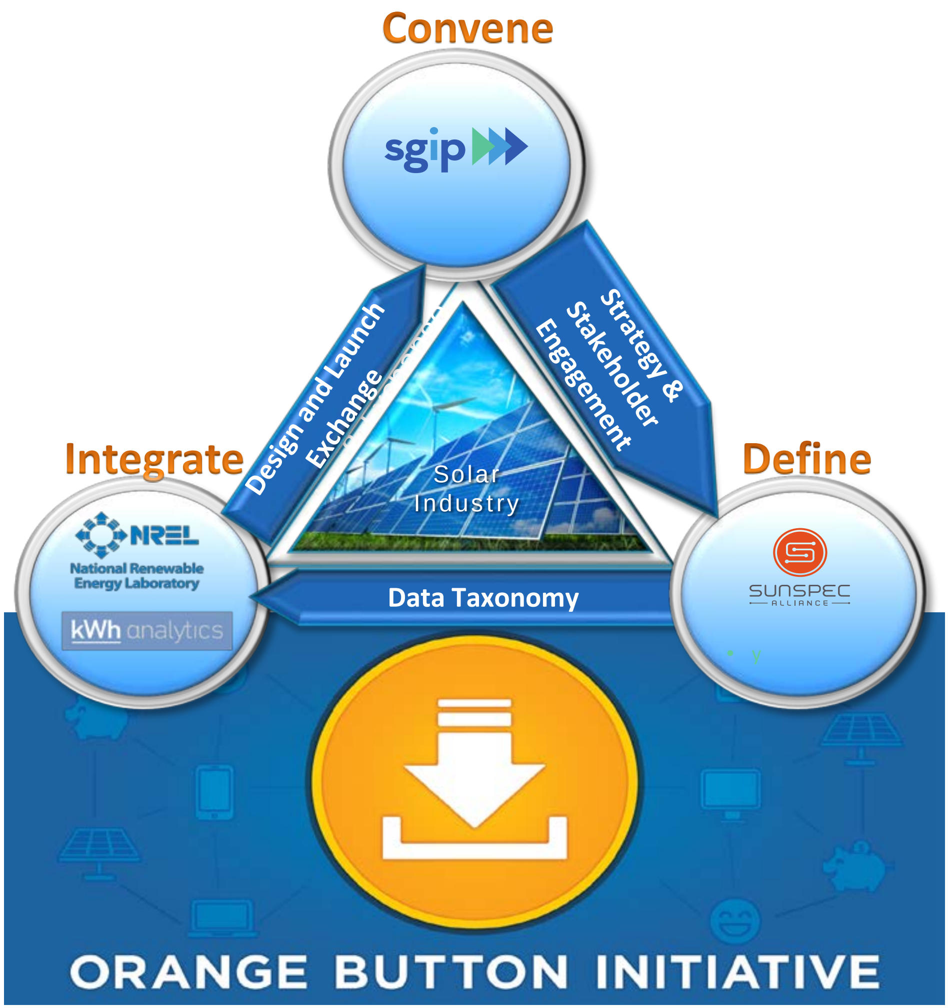
Key Observations:

1. Multi-Purpose Functions
2. Modular & Scalable HW&SW
3. End-to-End Situational Awareness
4. OT/IT/Telecom Convergence
5. **True Field Interoperability!**

2016 Key Technical Activities

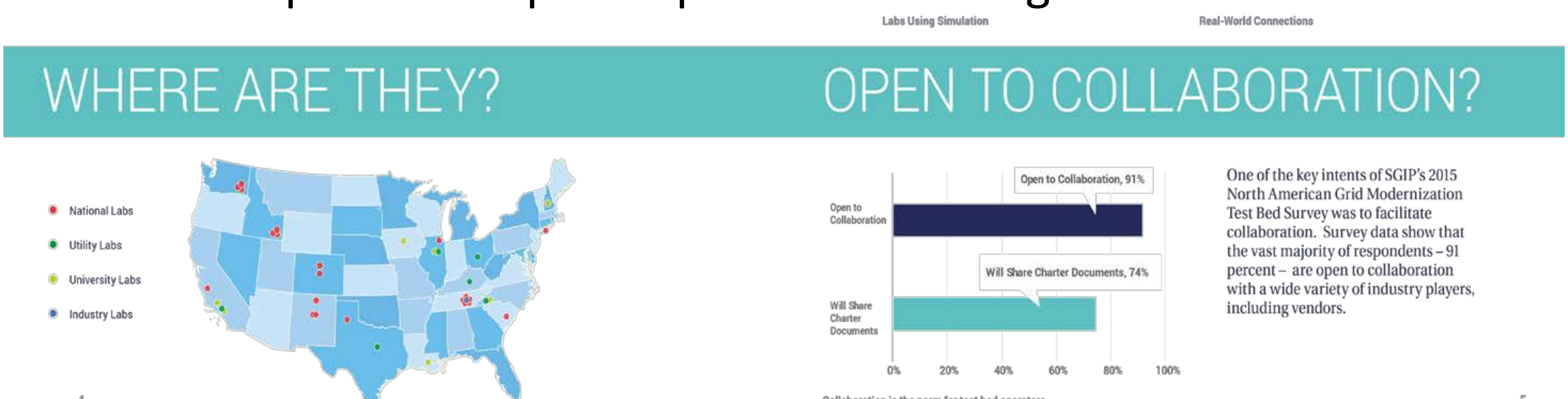
Orange Button℠

- SGIP was awarded $230,803 for 2016 through a competitive bid process for the Orange Button program. Orange Button is part of the DOE's SunShot initiative to drive down the cost of solar
- SGIP is to convene industry stakeholders, define the requirements needed to reduce costs associated with transmitting solar data, educate the industry of the value and success of the Orange Button program, and provide program management
- **305 Companies** registered on SGIP website to participate in the program with SGIP



2015 NA Grid Modernization Testbed Report

- Survey objective to increase awareness of smart grid testing activities underway, understand test lab capabilities, identify gaps in what is being tested, and support collaboration between test beds and industry
- Key Findings: Solar, storage and Microgrids are getting the most test bed attention; simulation was used by the majority of labs; Cybersecurity focus was surprisingly absent in lab responses on capabilities
- 2016 Report will expand upon 2015 Findings



2016 SGIP Technical Agenda Progress

Open Priority Action Plans

PAP	PAP Name	Status
15	Harmonize Power Line Carrier Standards for Appliance Communications in the Home	OPEN
17	Facility Smart Grid Information Standard	CLOSING
20	Green Button ESPI Evolution	OPEN
21	Weather Information	OPEN
22	EV Fueling Submetering Requirements	OPEN
23	Testing Profile for IEC 61850, Communication Networks and Systems in Substations	OPEN
24	Microgrid Operational Interfaces	OPEN
25	Orange Button: Harmonized Solar Asset Lifecycle Data	OPEN
26	OpenFMB: Distributed Intelligence	OPEN

Completed Priority Action Plans

PAP	PAP Name	Status
0	Meter Upgradeability Standard	CLOSED
1	Role of IP in the Smart Grid	CLOSED
2	Wireless Communications for the Smart Grid	CLOSED
3	Common Price Communication Model	CLOSED
4	Common Schedule Communication Mechanism	CLOSED
5	Standard Meter Data Profiles	CLOSED
6	Common Semantic Model for Meter Data Tables	CLOSED
7	Energy Storage Interconnection Guidelines DER/Elec. Storage Interconnection & Object Model Std	CLOSED
8	CIM/61850 for Distribution Grid Management	CLOSED
9	Standard DR and DER Signals	CLOSED
10	Standard Energy Usage Information	CLOSED
11	Common Object Models for Electric Transportation	CLOSED
12	Mapping IEEE 1815 (DNP3) to IEC 61850	CLOSED
13	Harmonization of IEEE C37.118 with IEC 61850 and Precision Time Synchronization	CLOSED
14	T&D Power Systems Model Mapping	CLOSED
16	Wind Plant Communications	CLOSED
18	SEP 1.x to SEP 2 Transition and Coexistence	CLOSED
19	Wholesale Demand Response (DR) Communication Protocol	CLOSED

Stakeholder Technical Health Assessment

- In 2015 the SGIP Technical Committee formed a panel to assess the health of SGIP stakeholder technical working groups and to analyze meeting frequency, attendance, activities, and deliverables
- Common issues identified were limited participation, identifying relevant work, and concern that scope of work is limited due to resource constraints
- Recommendations and organizational changes implemented included:
  - **Organizational Changes:**
    - Consolidation of the Industry to Grid, Building to Grid, and Home to Grid working groups
    - Disbanding the Vehicle to Grid working group
    - Disbanding the Transmission and Distribution working group
  - **Managerial Focus:**
    - Recruitment of key stakeholders
    - Conduct regular leadership elections
    - Enforce proper meeting management
    - Increased external organization coordination
    - Development of a strategic technical vision and plan

Milestone Reached - IPRM

- National Electrical Manufacturers Association (NEMA) has published ANSI/NEMA SG-IPRM 1-2016 10-2015: Smart Grid Interoperability Process Reference Manual
- The standard was a joint effort by the NEMA Distribution Automation Technical Committee and SGIP's Smart Grid Testing and Certification Committee (SGTCC)
- The IPRM contains Testing and Certification recommendations and best practices that promote the introduction of interoperable products in the marketplace
- ***Next Step:*** SGIP's SGTCC assembling a subgroup to write an IRPM User's Guide


Approved American National Standard
ANSI

Approved as an American National Standard
ANSI Approval Date: February 22, 2016

NEMA Standards Publication SG-IPRM 1-2016

Smart Grid Interoperability Process Reference Manual

Published by

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, VA 22209

www.nema.org

Milestone Reached – PAP-17

PAP-17: Facility Smart Grid Information Model (FSGIM) : Developed a data standard that provides a basis for common information exchange between control systems and end use devices in commercial and industrial facilities

- On May 2nd, ANSI provided final approval of ASHRAE/NEMA/ANSI Standard 201: ***Facility Smart Grid Information Model (FSGIM)***
- SGIP's PAP-17 started in 2010 and is a foundational piece that refined the use cases in the standard
- NIST's Steve Bushby led the PAP-17 team and the ASHRAE joint Standard Project Committee that developed Standard 201
- All PAP deliverables are complete and ASHRAE/NEMA/ANSI Standard 201 is a Catalog of Standards candidate

2016 SGIP Technical Agenda Progress

Catalog of Standards Reviews Underway

Source:	Standard Number:	Standard Name:
H2G DEWG	ANSI/CEA-2045	Consumer Electronics Energy Usage Information (CE-EUI)
PAP-15	ITU-T G.9903	Narrowband orthogonal frequency division multiplexing power line communication transceivers for G3-PLC networks
PAP-17	ASHRAE/NEMA/ANSI Standard 201	Facility Smart Grid Information Model (FSGIM)
PAP-26	NAESB RMQ.26	NAESB OpenFMB Model Business Practices
SGTCC	ANSI/NEMA SG-IPRM 1-2016 10-2015	Smart Grid Interoperability Process Reference Manual

Catalog of Standards now has 76 entries

Will launch CoS Navigation Tool later this year.

SGIP 2016 Annual Conference

Confirmed Speakers:

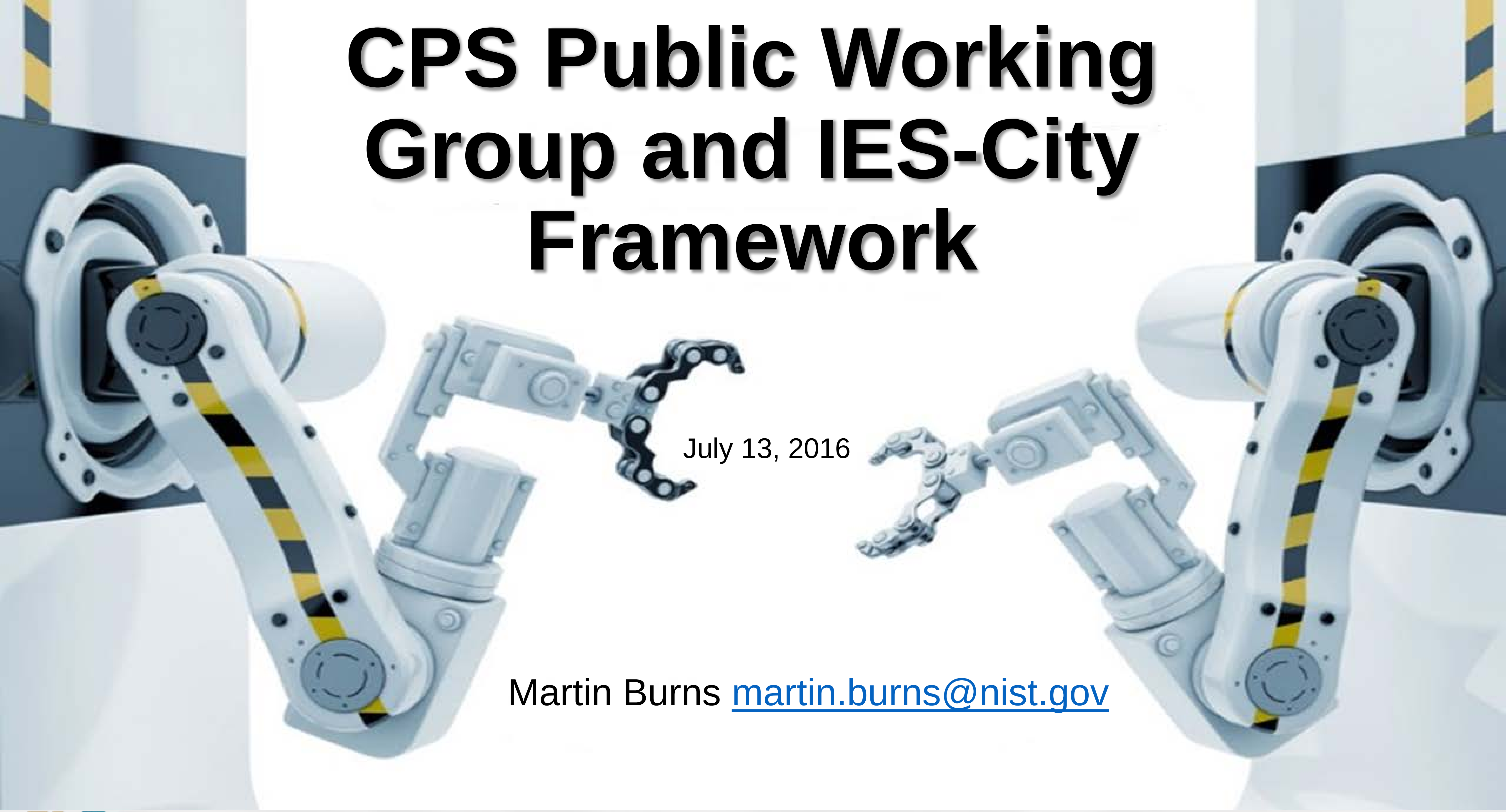
- Anne Pramaggiore – President and CEO of ComED
- Allan Schurr - President of Edison Energy
- Michael Bates – Global Energy Director, Intel

Program Includes: SGIP Annual Meeting, Stakeholder Working Group Meetings, Networking, Vendor Exposition, OpenFMB Demonstrations

Conference Sessions:

- Managing Change with Distributed Resources
- Regulatory Policy & Distributed Energy Resources
- Grid Architecture in a Distributed World
- Managing Change in the New Energy Economy
- Department of Energy's Grid Modernization Laboratory Consortium (GMLC)
- Intelligent Distribution – An Update from the Field
- Energy IoT - Moving from Millions to Billions to Trillions of Devices

Thank you



CPS Public Working Group and IES-City Framework

July 13, 2016

Martin Burns martin.burns@nist.gov

CPS Framework

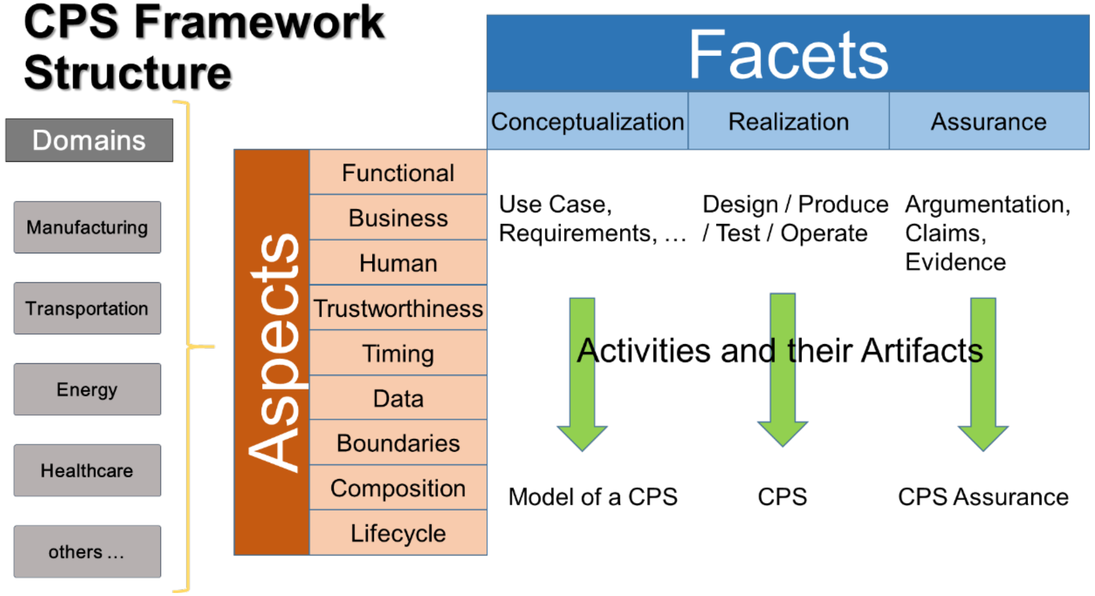
CPS Framework

- Two years of effort resulting in consensus release 1.0
  - Several hundred collaborators – academic, industry, government
- CPS Framework provides a common basis for studying/designing/analyzing Cyber-Physical Systems
- The Smart Grid is a domain in the realm of CPS
- Helping to migrate concepts to industry
  - SAE Collaboration on advanced transportation systems
  - Open Source Project to enable tool development
- “Deeper dive” into “Trustworthiness Aspect”

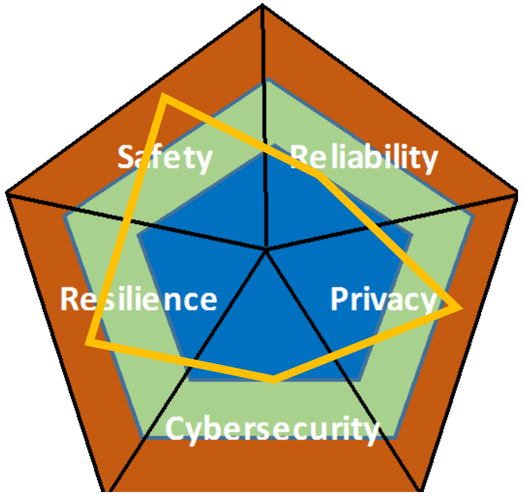
CPS Public Working Group

- Provides technical, concern-driven foundation for CPS/IoT: CPS Framework
- NIST leadership w/industry, academia, government; CPS experts in 5 working groups have contributed to draft CPS Framework, now being revised based on public review comments
- EL, ITL, PML collaborative effort (Overall leads: Griffor, Wollman – plus Burns, Battou, Simmon, Quinn/Pillitteri, Weiss)
- Collaboration site: https://pages.nist.gov/cpspwg/

'Concern-driven': holistic, integrated approach to CPS concerns.

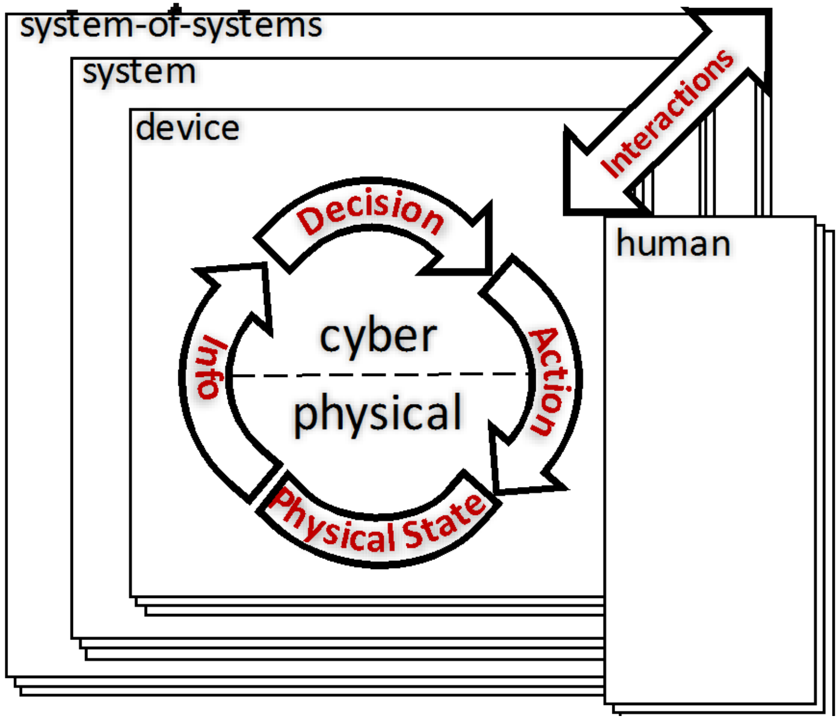


Concerns as Dimensions of CPS Measurement

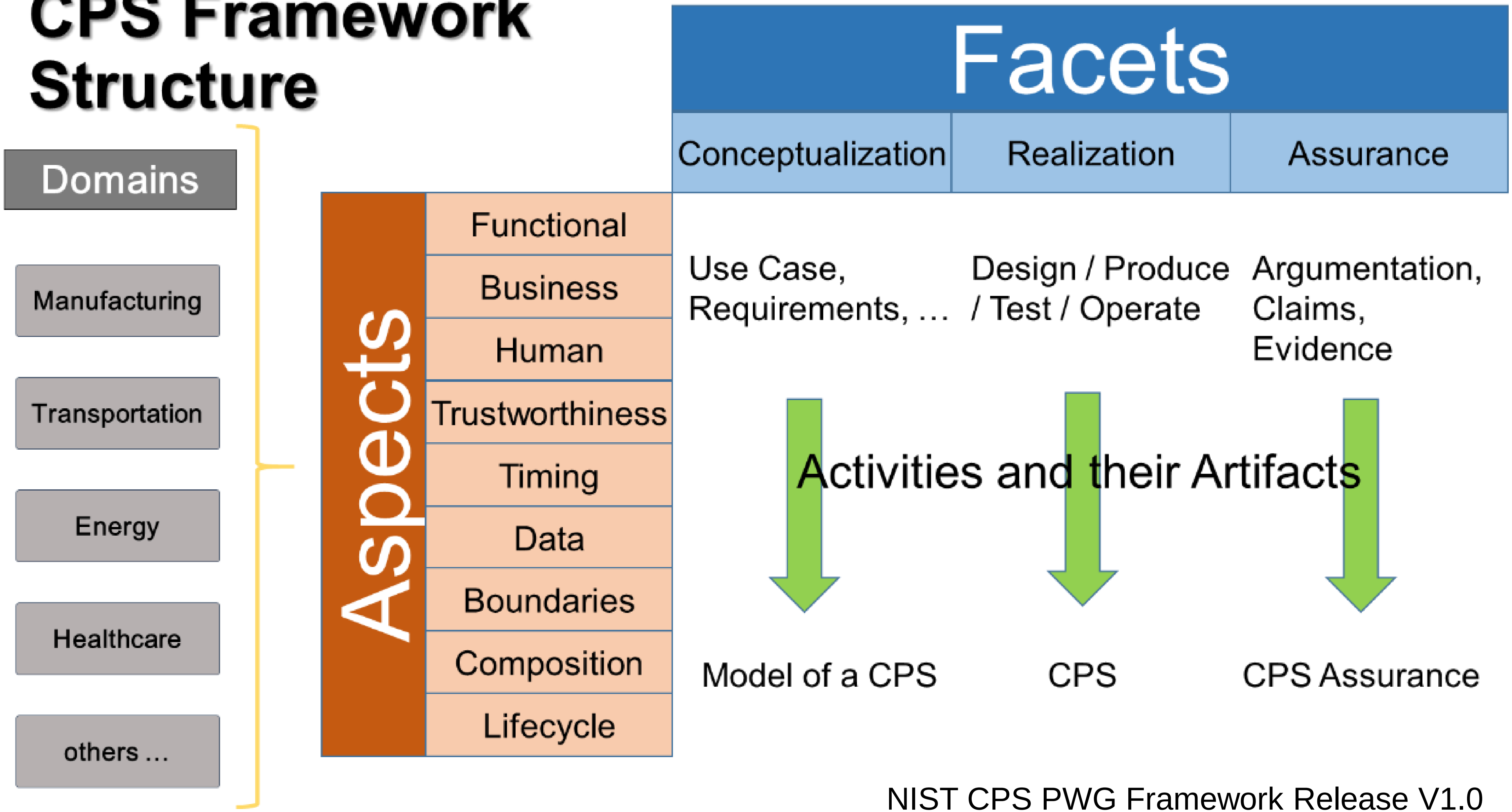


What is a Cyber-Physical System?

- Elements
  - o Information - Sensing/Awareness – Interpreting measurement of physical state
  - o Decision – Logic, Computation
  - o Action – Impacting physical state
  - o Interactions – across the CPS
- Scope
  - o Expanded by increasing deployment
  - o Cross-Domain Applications – pose challenges to interpreting measurement
- Scale
  - o Small and medium scale up to city/nation/world



CPS Framework Structure



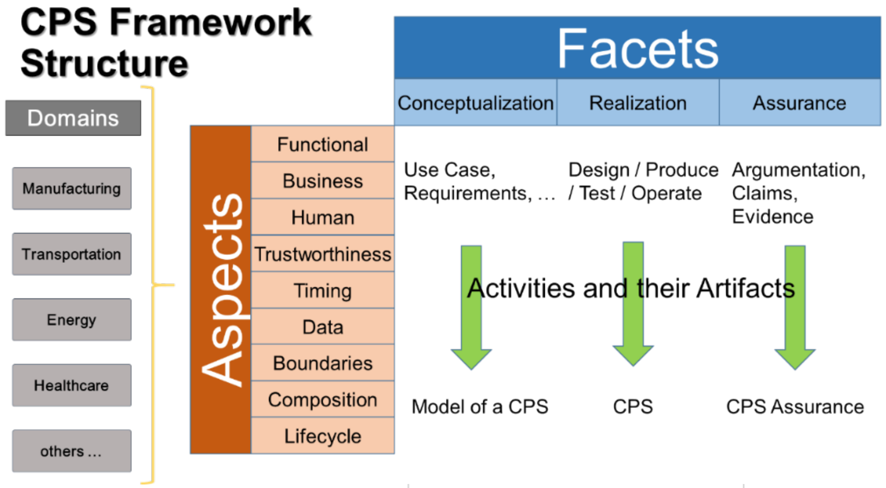
NIST CPS PWG Framework Release V1.0

Holistic Concern-Driven Analysis

Common Concern:
Trustworthiness.Security.Cybersecurity.confidentiality

Clause in document:
TS-0002 clause 6.4

Solution: Access Control and Authorization, TS-0003 clause 7



Technology level (Device, System, System of Systems)
Technology scope description (text)

Concern	Aspect/Concern	Discussion of Concern	Discussion Reference(s)	Solution	Solution Reference(s)
Functional	Functional	in general	n/a		
Trustworthiness	Trustworthiness				
privacy	privacy	authorization, privacy and all the security requirements are defined	TS-0002 clause 6.4	Use proper access control settings under control of the data subject (individual whose privacy is exposed by the data)	TS-0003 Clause 7
reliability	reliability	in terms of message delivery, yes	tbd	CMDH(connection management and delivery handling) CSF and its resource types	TS-0001 clause 6.2.2
resilience	resilience	in terms of message delivery, yes	tbd	CMDH(connection management and delivery handling) CSF and its resource types	TS-0001 clause 6.2.2
safety	safety	Every deployment requires a risk and vulnerability assessment	TR-0008	Perform proper risk and vulnerability assessment and mitigate unacceptable risks	Any Risk assessment methodology. See TR-0008
security	security	all the security requirements are defined	TS-0002 clause 6.4, TR-0008	Definition of 4 protection levels suitable for different exposures. Definitrion of security frameworks to protect assets	TS-0003
cybersecurity	cybersecurity	all the security requirements are defined	TS-0002 clause 6.4	CPS security implies cybersecurity with additional challenges. Sdolutions exist to mitigate risks down to acceptable levels!	TR-0008; TS-0003
confidentiality	confidentiality	all the security requirements are defined	TS-0002 clause 6.4	Access Control and Authorization	TS-0003 clause 7
integrity	integrity	all the security requirements are defined	TS-0002 clause 6.4	implement proper protection level	TR-0008; TS-0003
availability	availability	Risks related to Denial of Service must be mitigated	TR-0008	Some mitigatoion mechanisms exist	TR-0008, TS-0003

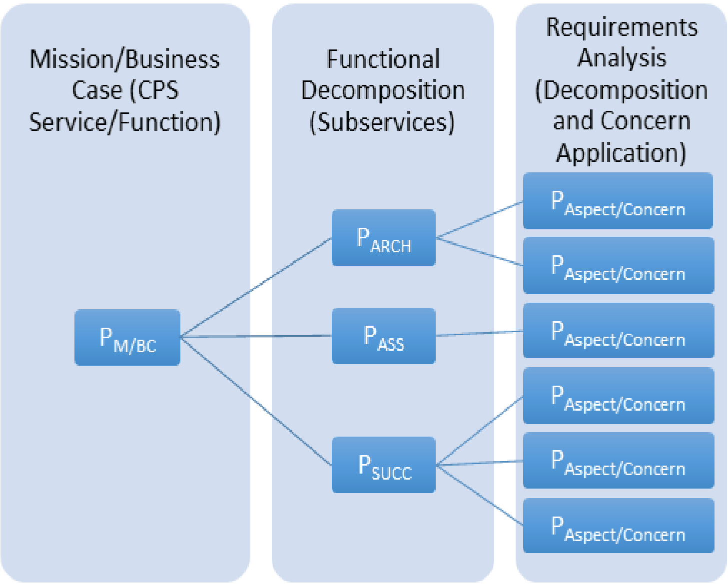
CPS Framework Mathematics

property-Tree of a CPS

Legend

$P_{M/BC}$ = Mission/Business Case
P_{ARCH} = Integration Steps
P_{ASS} = Assumptions
P_{SUCC} = Success Criteria
$P_{Aspect/Concern}$ = Aspect/Concern

- Branches capture the 'genealogy' of a property
- Branching gives assurance conditions for the branching node property
- Concerns may give rise to multiple properties in the Functional Decomposition
- 'Edges' should be read 'depends on' (L2R) or 'needed to satisfy' (R2L)



semantics of CPS Framework

$$P \in \overline{Concern}^{CPS}$$

$$\bar{P}^{CPS} = \{tests\ T\ for\ P\}$$

$$Supp_M(T) = \{measurement\ support\ \mu_1, \ldots, \mu_k\ of\ T\}$$

$$\overline{Evidence}^{CPS}(P) = \sum_{T \in \bar{P}^{CPS}} \bar{T}^{CPS}$$

… defines **composition of concerns**

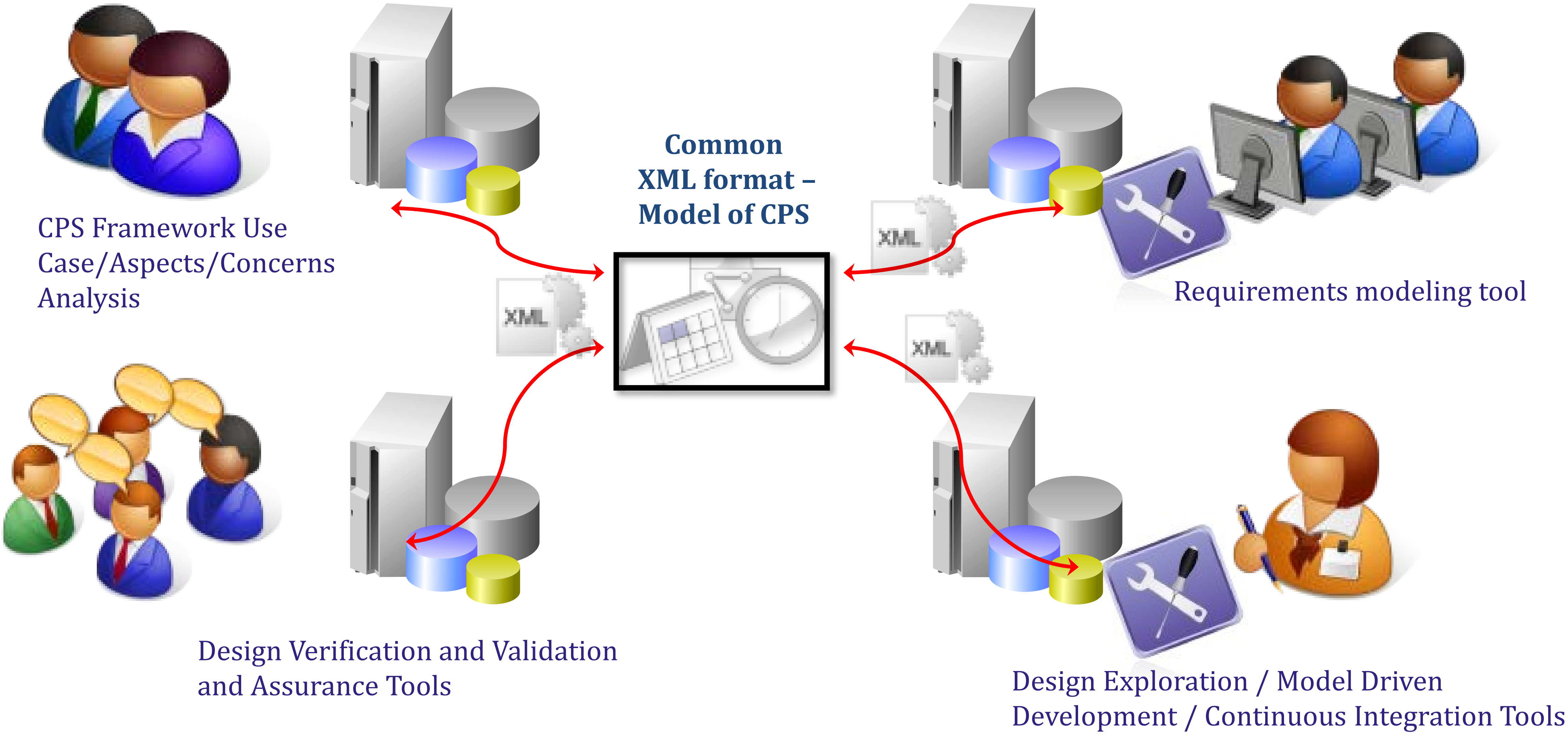
$$\overline{C_1 * C_2}^{CPS} = \overline{C_1}^{CPS} \cup \overline{C_2}^{CPS}$$

formal methods for assurance of a CPS

$$< d, e, a > \in P(CPS)\ \equiv_{Def}\ design\ element\ d, test\ evidence\ e\ are\ sufficient\ based\ on\ argument\ a\ to\ conclude\ that\ the\ CPS\ satisfies\ P$$

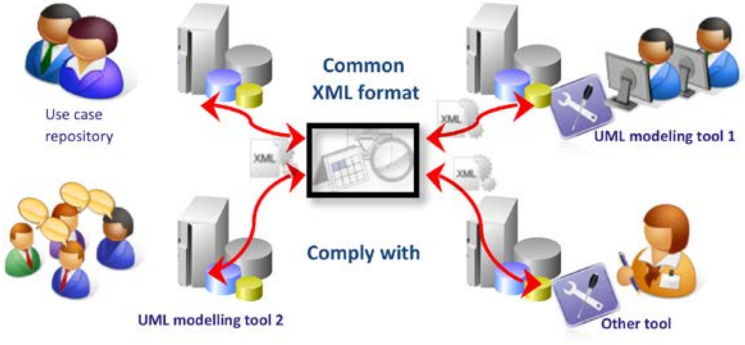
$$\overline{Assurance\ Case}^{CPS} = \sum_{C \in Aspect^{CPS}} \sum_{P \in \bar{C}^{CPS}} \sum_{d \in Design^{CPS}} \sum_{e \in Evidence(P)^{CPS}} \overline{Argumentation}^{CPS}(P)$$

Framework Open Source Project:
Tool Exchange Format for Holistic Concern-driven Systems Engineering

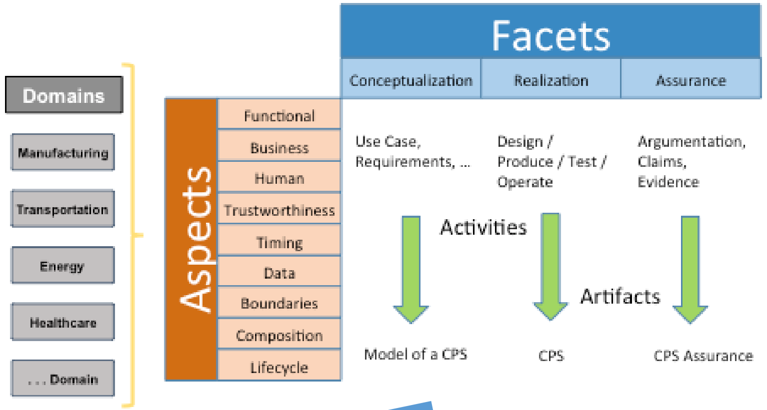


Framework Modeling and Open Source Tools

High-Level Representation of CPS (IEC 62559 Use Case Methodology)



Concern/Property Driven CPS Process: Framework Methodology



UML

Standardized XML Schema

Canonical XML Representation of CPS

Conceptualization
- Business Case
- Use Case
- Requirements

Realization
- Design
- Traceability to Requirements

Assurance
- Algorithmically Prove Design Meets Requirements

IEC 62559 Use Case Methodology → **CPS Framework UML Model** → **CPS Framework Model Documentation** → **CPS Framework Open Source Project Workshop 4Q 2016**

Extended and Usable CPS Framework Tools

IEC 62559-2 MSWord™ Use Case Template

1 Description of the Use Case

1.1 Name of Use Case

Use case identification		
ID	Area/ Domain(s)/ Zone(s)	Name of Use Case

1.2 Version Management

Version management			
Version No.	Date	Name Author(s)	Changes

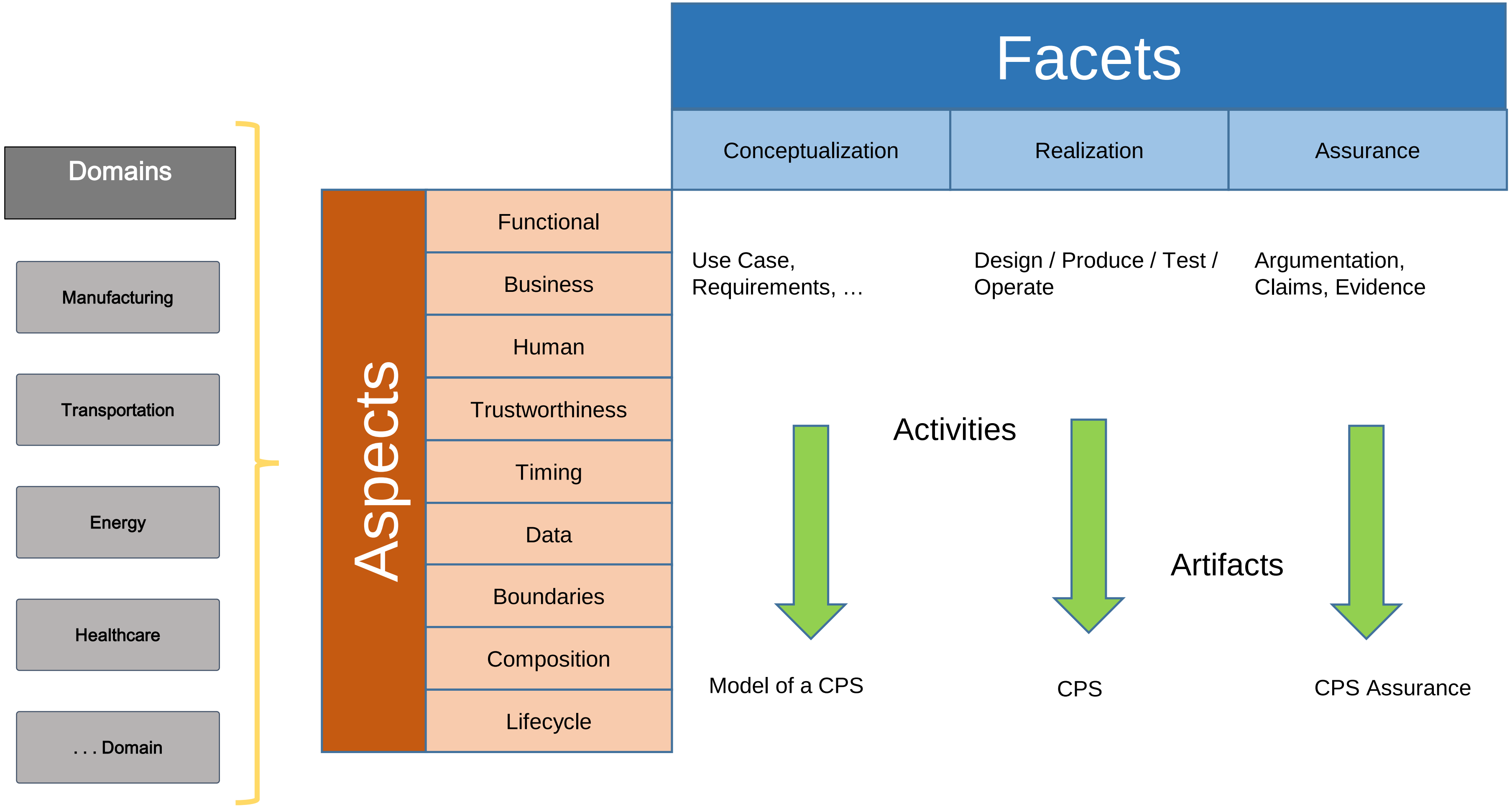
1.3 Scope and Objectives of Use Case

Scope and objectives of use case	
Scope	
Objective(s)	
Related business case(s)	

1.4 Narrative of Use Case

Narrative of use case
Short description
Complete description

NIST PWG CPS Framework Release 1.0



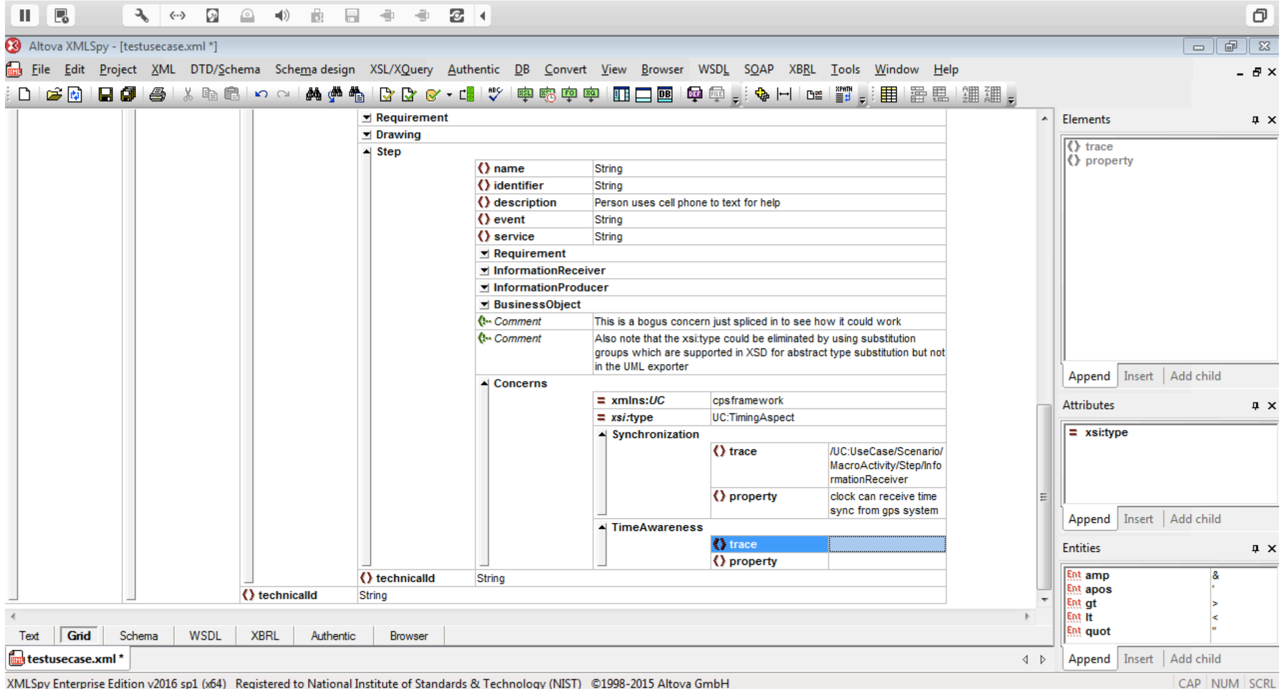
Open Source Tool Development

Enterprise Architect: UML Editor

XMLSpy: XML/XMLSchema Editor

ALTOVA® XMLSpy® 2016

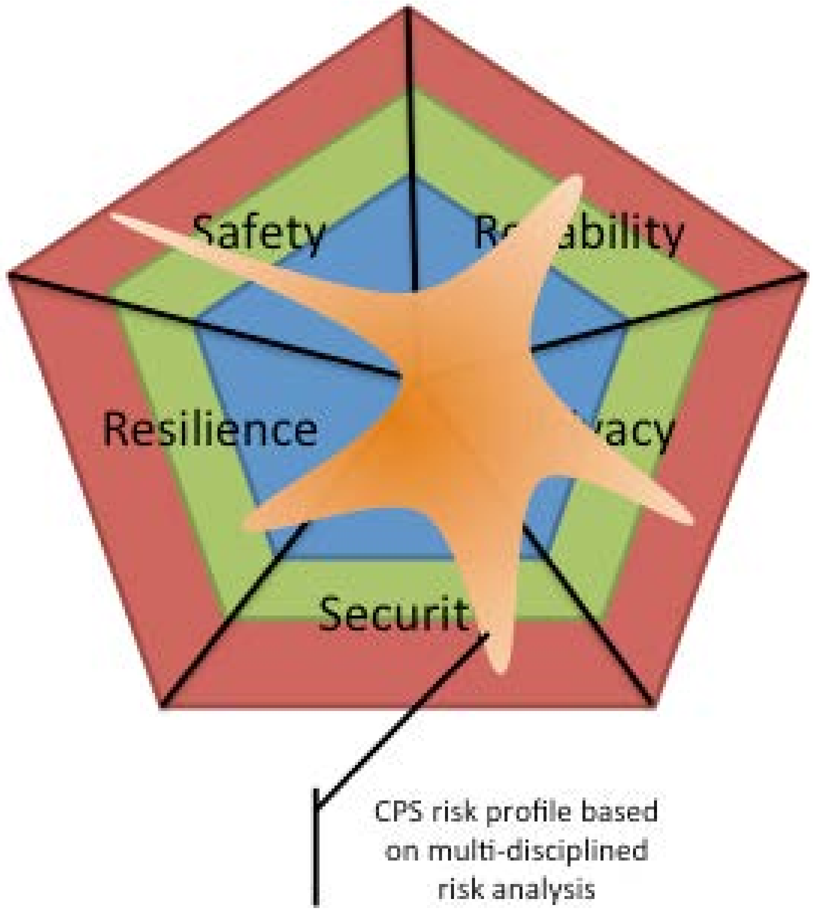
Tool Interchange Data Set



Trustworthiness Aspect – Avoidance of Harm

Trustworthiness:

- o Security
- o Privacy
- o Safety
- o Reliability
- o Resilience



IES-City Framework

IoT-Enabled Smart City Framework

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

FIWARE MSIP NIST National Institute of Standards and Technology U.S. Department of Commerce ETSI World Class Standards ANSI USGBC ENEA Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Goal: A reference framework for the development incremental and composable Smart Cities

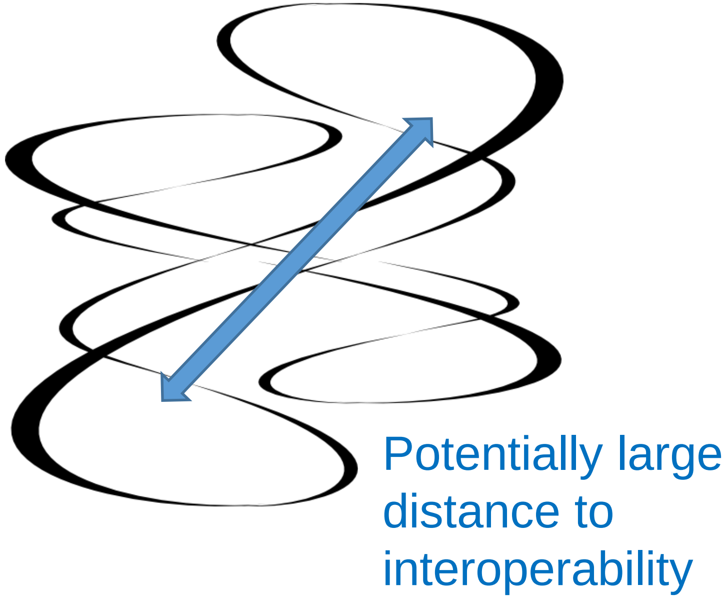
Pivotal Points of Interoperability - PPI

- If you standardize everything, you freeze out innovation.
- If you standardize nothing, you get non-interoperable clusters that can't be easily integrated.

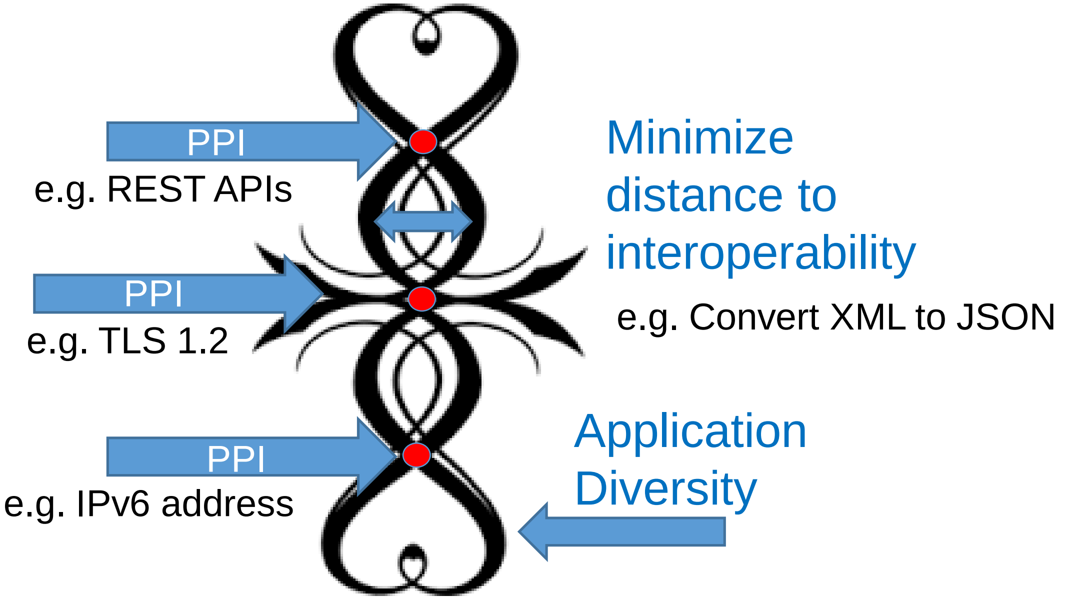
⌘ The principle of Pivotal Points of Interoperability is to find consensus standardized interfaces that deal with composition of CPS without constraining innovation.

Pivotal Points of Interoperability (PPI)

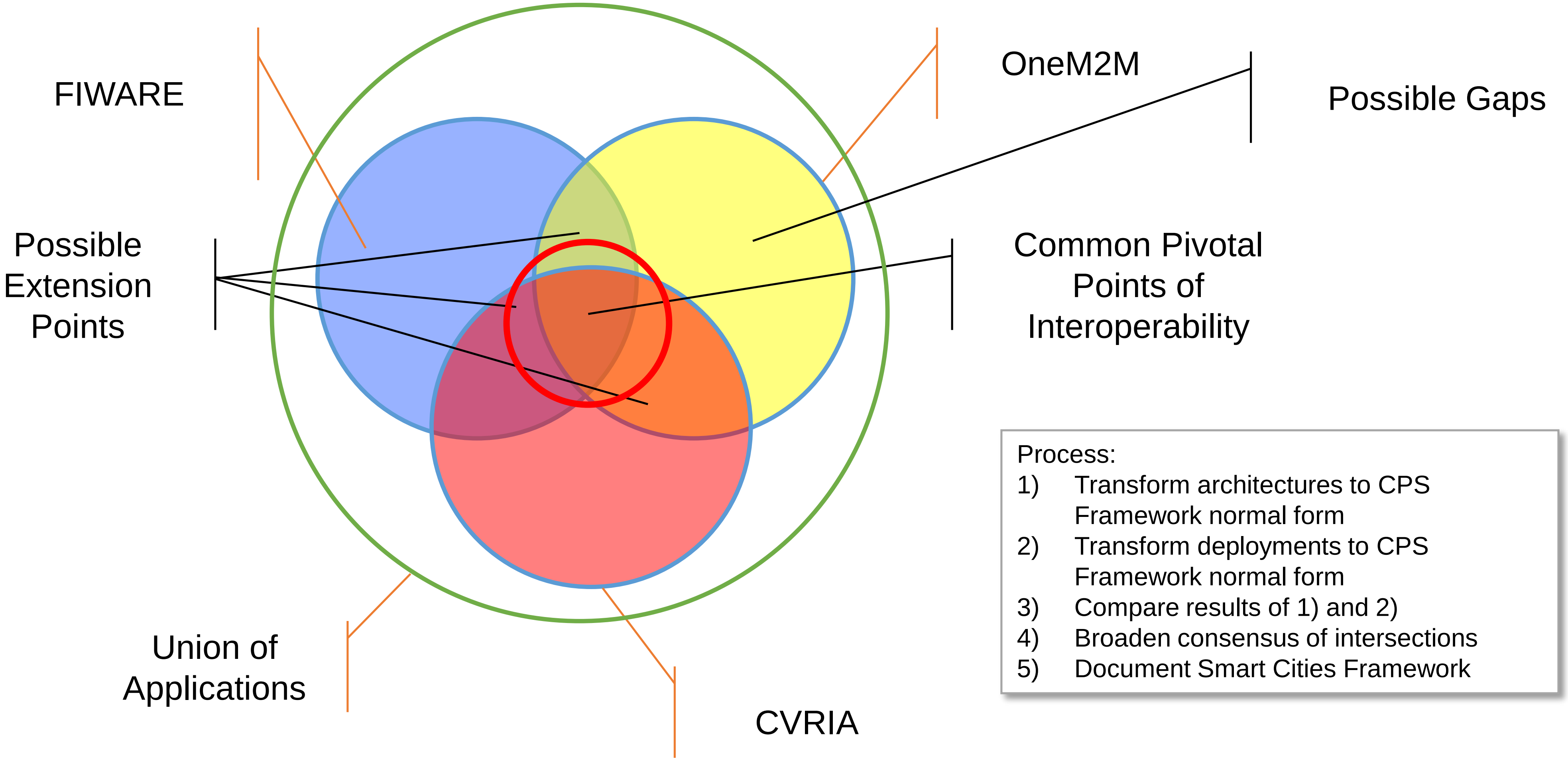
Independent technology deployments



With Pivotal Points of Interoperability



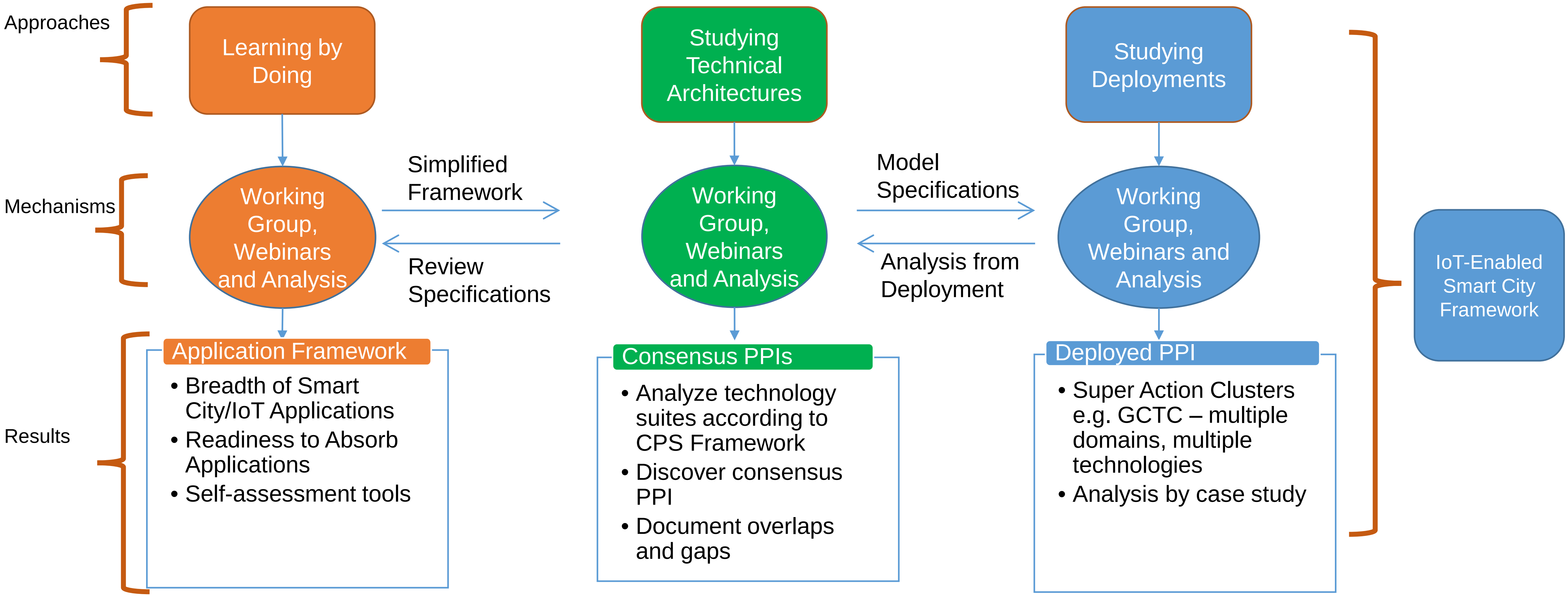
How to Discover Consensus



Process:

1) Transform architectures to CPS Framework normal form
2) Transform deployments to CPS Framework normal form
3) Compare results of 1) and 2)
4) Broaden consensus of intersections
5) Document Smart Cities Framework

Public Working Groups



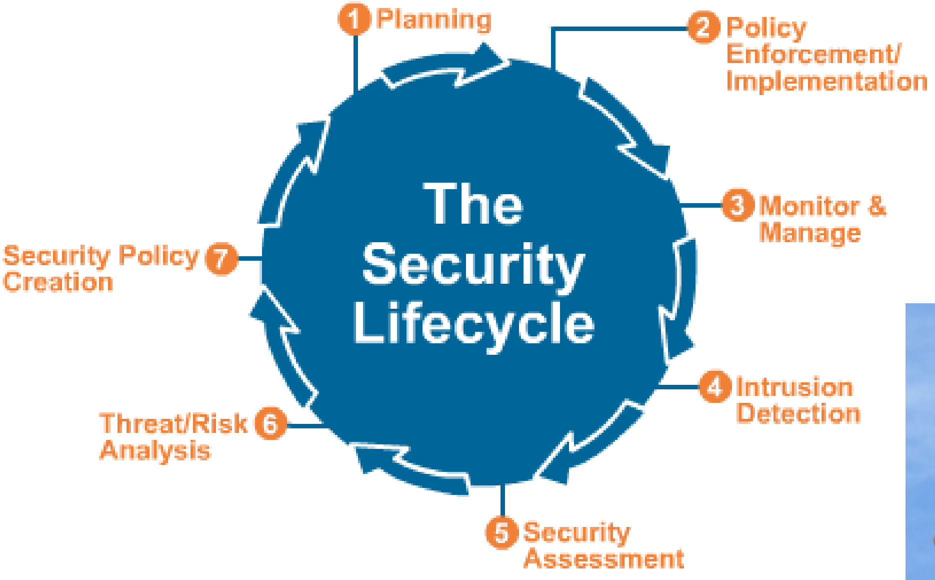
Participants: City leaders (includes CTOs, CIOs, Innovation Officers), Experts, Companies, Technical Stakeholders, Researchers …

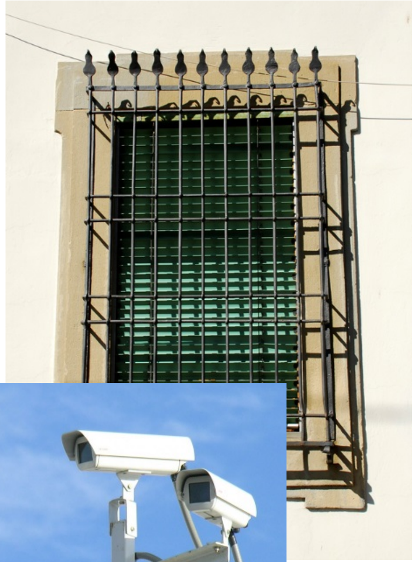
spare

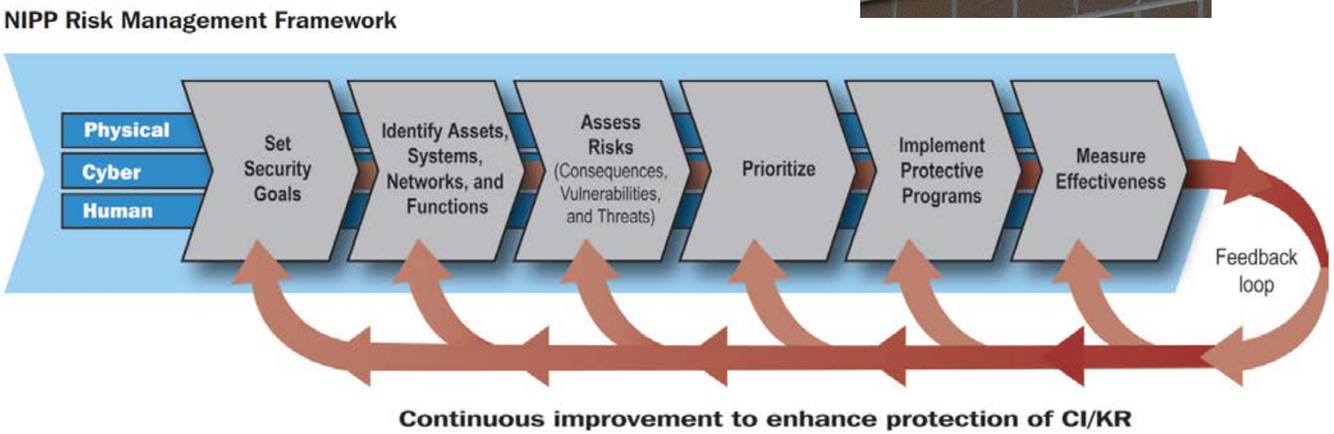
Risk Management – Wikipedia

- **Risk management** is the identification, assessment, and prioritization of risks (defined in ISO 31000 as the effect of uncertainty on objectives) followed by coordinated and economical application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. Objective is to assure uncertainty does not deflect the endeavor from the business goals.
- **Method**: For the most part, these methods consist of the following elements, performed, more or less, in the following order.
    1. identify, characterize threats
    2. assess the vulnerability of critical assets to specific threats
    3. determine the risk (i.e. the expected likelihood and consequences of specific types of attacks on specific assets)
    4. identify ways to reduce those risks
    5. prioritize risk reduction measures based on a strategy
- **Composite risk index = impact of risk event x probability of occurrence**

Risk Management – Security







Risk Management – Cybersecurity

Well-known 800 series NIST Special Publications.

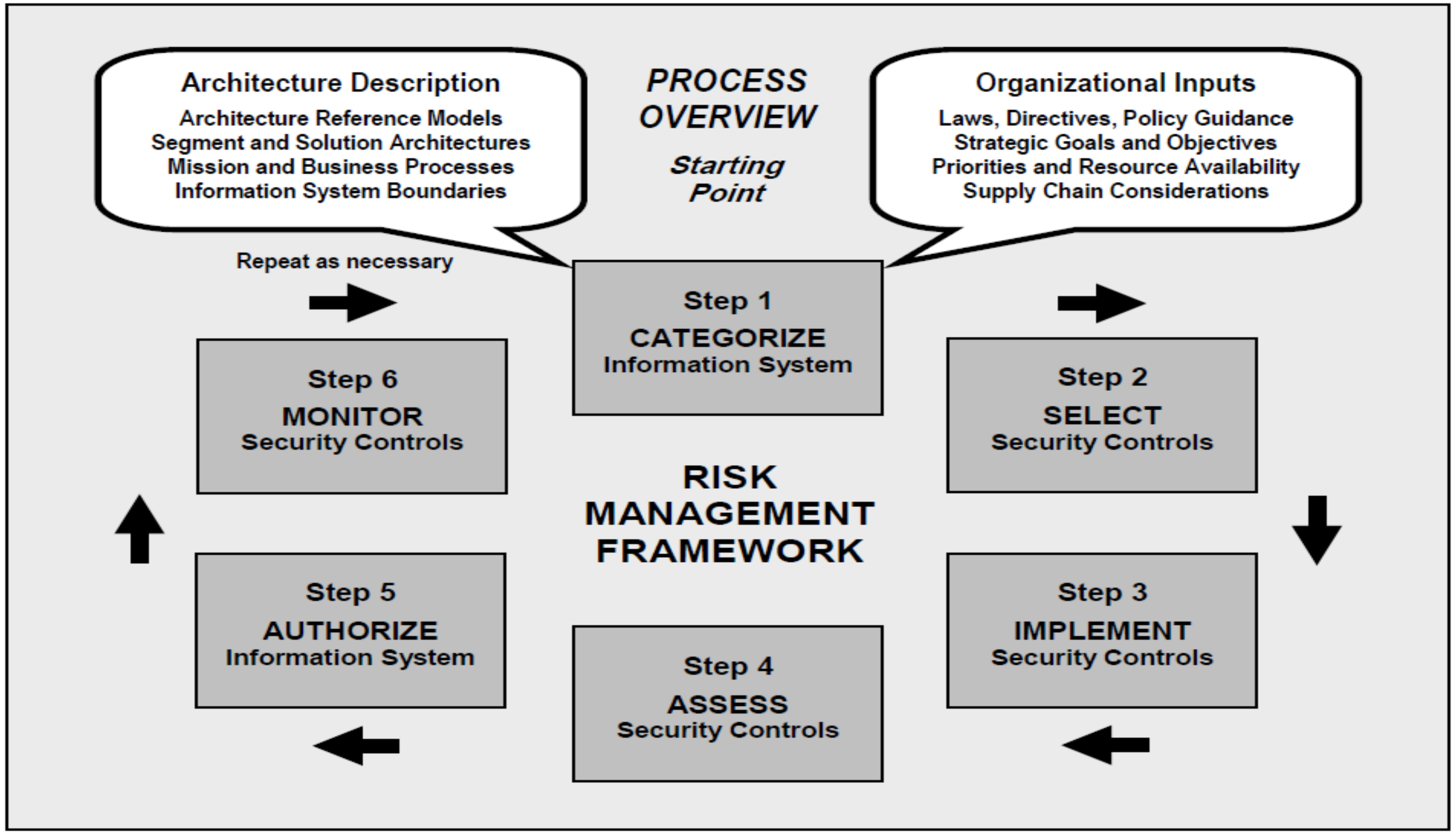
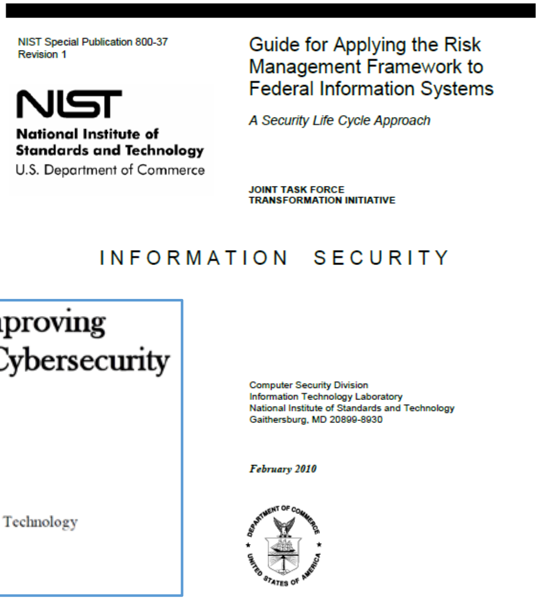
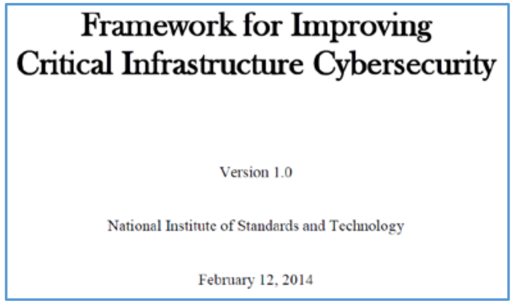
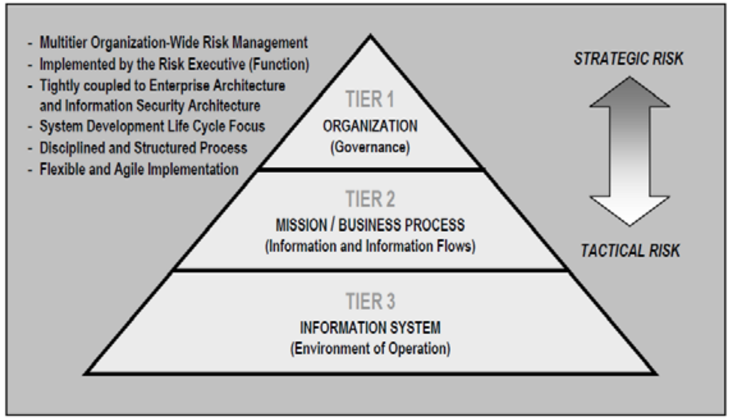


FIGURE 2-2: RISK MANAGEMENT FRAMEWORK







Cybersecurity objectives: Confidentiality, Integrity, Availability

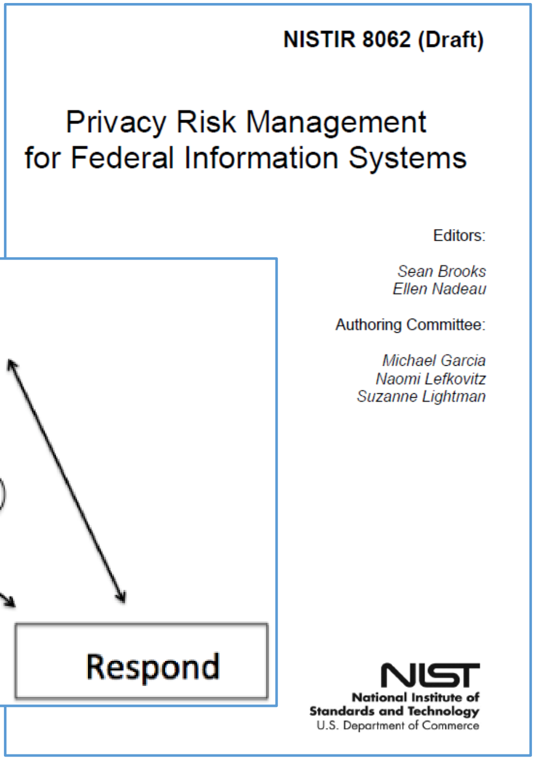
Risk Management – Privacy

NIST Draft Privacy Risk Management Framework

Released for comments June 5, 2015

NISTIR 8062 Includes:

- Common vocabulary
- Objectives to facilitate Privacy Engineering
- Risk model for assessing privacy risk in information systems


NISTIR 8062 (Draft)

Privacy Risk Management
for Federal Information Systems

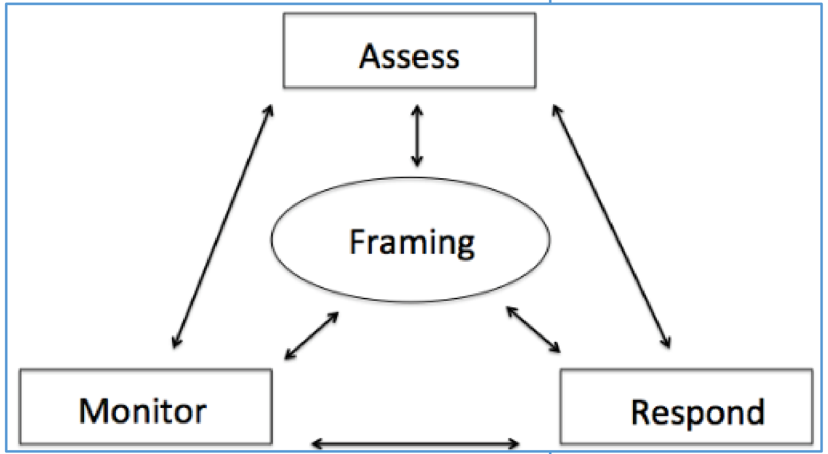
Editors:

Sean Brooks
Ellen Nadeau

Authoring Committee:

Michael Garcia
Naomi Lefkovitz
Suzanne Lightman

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



NIST has developed three privacy engineering objectives

- **Predictability** is the enabling of reliable assumptions by individuals, owners, and operators about personal information and its processing by an information system.
- **Manageability** is providing the capability for granular administration of personal information including alteration, deletion, and selective disclosure.
- **Disassociability** is enabling the processing of personal information or events without association to individuals or devices beyond the operational requirements of the system.

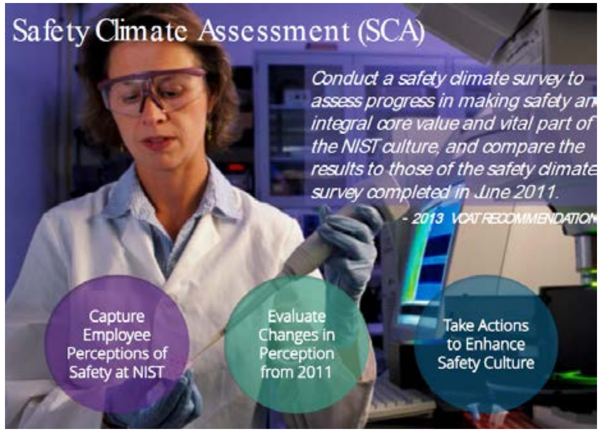
Privacy Risk = likelihood of a problematic data action x impact of a problematic data action

6 processes
Frame business objectives
Frame organizational privacy governance
Assess system design
Assess privacy risk
Design privacy controls
Monitor change

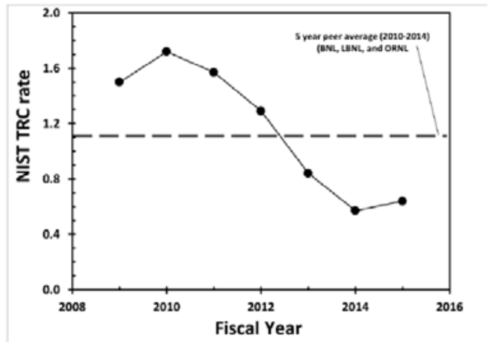
Risk Management – Safety

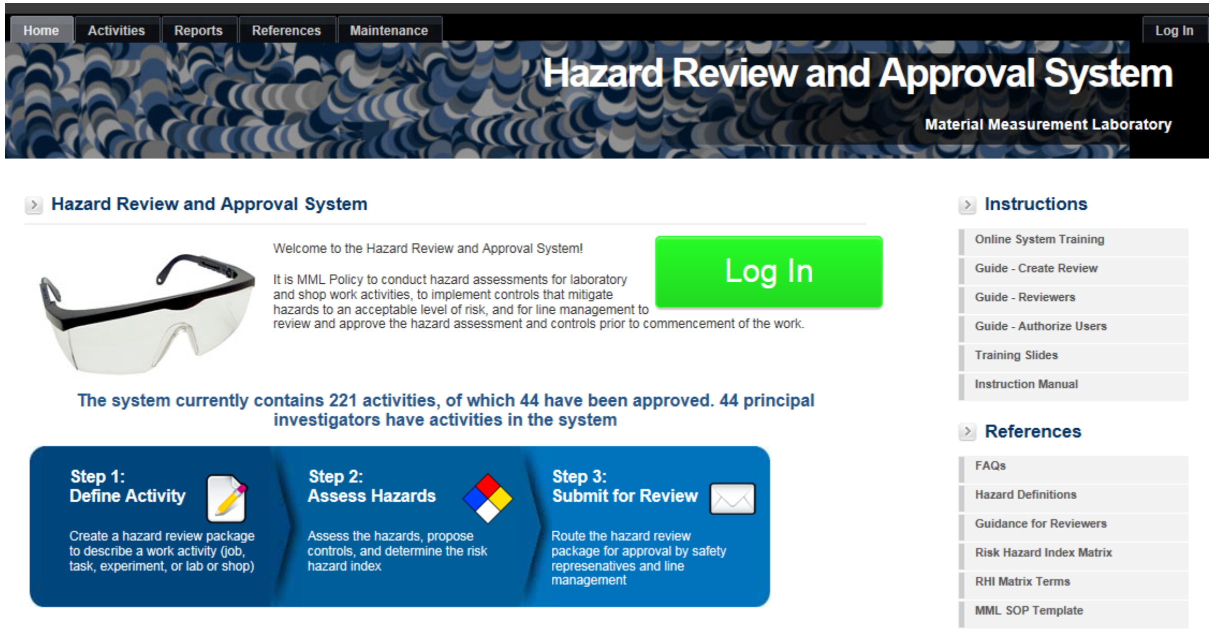
Hazard Review Matrix

LIKELIHOOD OF OCCURRENCE		POTENTIAL SEVERITY OF THE CONSEQUENCES OF A HAZARDOUS EVENT OR EXPOSURE TO A HAZARD			
		Catastrophic Death or permanent disability System or facility loss Lasting environmental or public-health impact	**Severe** Serious injury; temporary disability Subsystem loss or significant facility/property damage Temporary environmental or public-health impact	**Moderate** Medical treatment beyond first aid; lost-work-day(s) More than slight facility/property damage External reporting requirements; more than routine clean-up	**Minor** First-aid only Negligible or slight facility/property damage No external reporting requirements; routine clean-up
	Frequent Likely to occur repeatedly	CRITICAL RHI=4 Not Permitted	CRITICAL RHI=4 Not Permitted	SERIOUS RHI=3 OU Level FLHR[2]	Medium RHI=2 Division level FLHR
	Probable Likely to occur multiple but infrequent times	CRITICAL RHI=4 Not Permitted	CRITICAL RHI=4 Not Permitted	SERIOUS RHI=3 OU Level FLHR[2]	Medium RHI=2 Division level FLHR
	Occasional Likely to occur at some time	CRITICAL RHI=4 Not Permitted	SERIOUS RHI=3 OU Level FLHR[2]	Medium RHI=2 Division level FLHR	Low RHI=1 Group level FLHR No EL SP review
	Remote Possible, but not likely to occur	SERIOUS RHI=3 OU Level FLHR or Division level if FCIS[3]	Medium RHI=2 Division level FLHR or Group level if FCIS[3]	Medium RHI=2 Division level FLHR or Group level if FCIS[3]	Low RHI=1 Group level FLHR No EL SP review
	Improbable Very unlikely; can reasonably assume it will	Medium RHI=2 Division level FLHR	Low RHI=1 Group level FLHR	Low RHI=1 Group level FLHR No EL SP review	Minimal RHI=0 Group Level FLHR No EL SP review

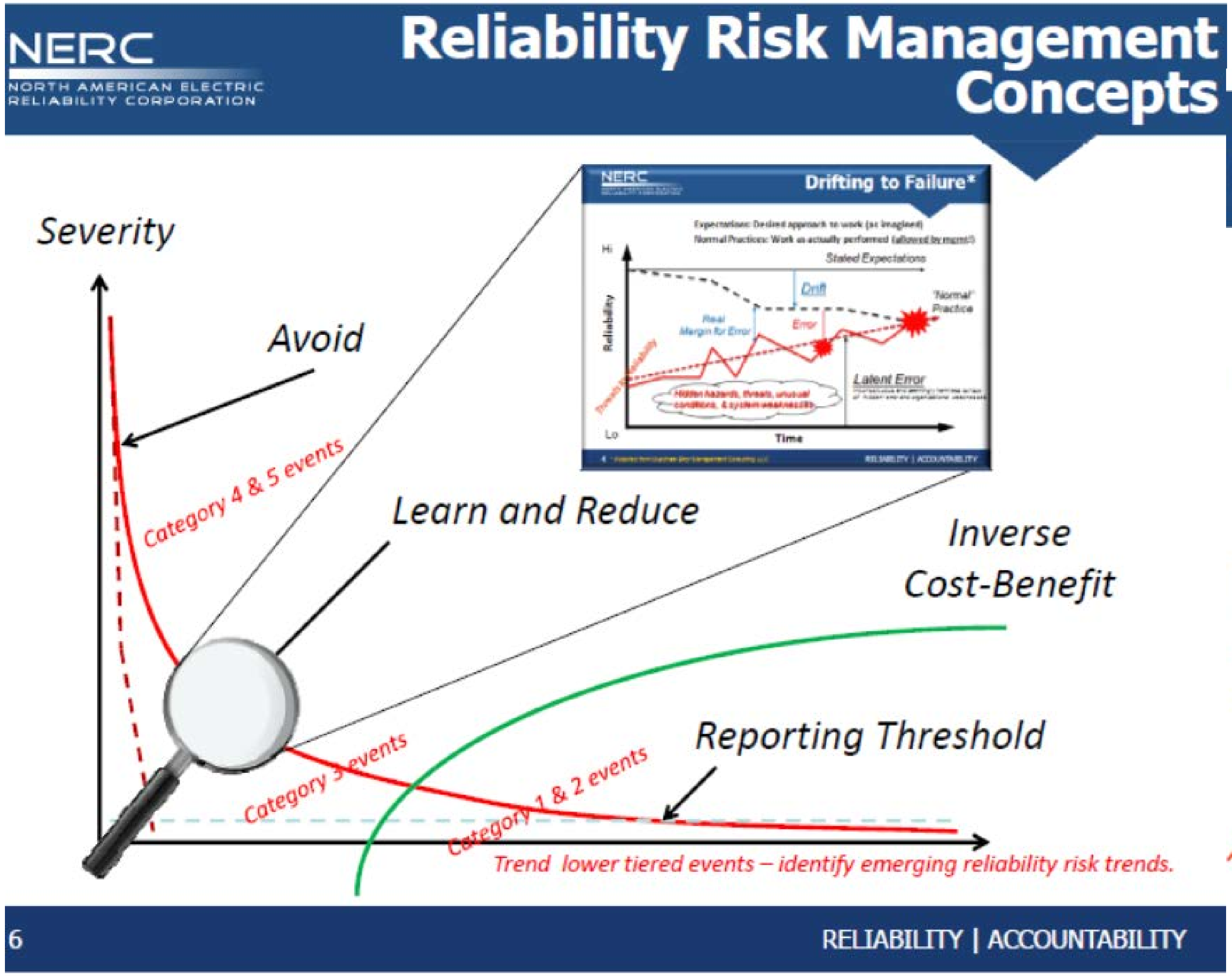


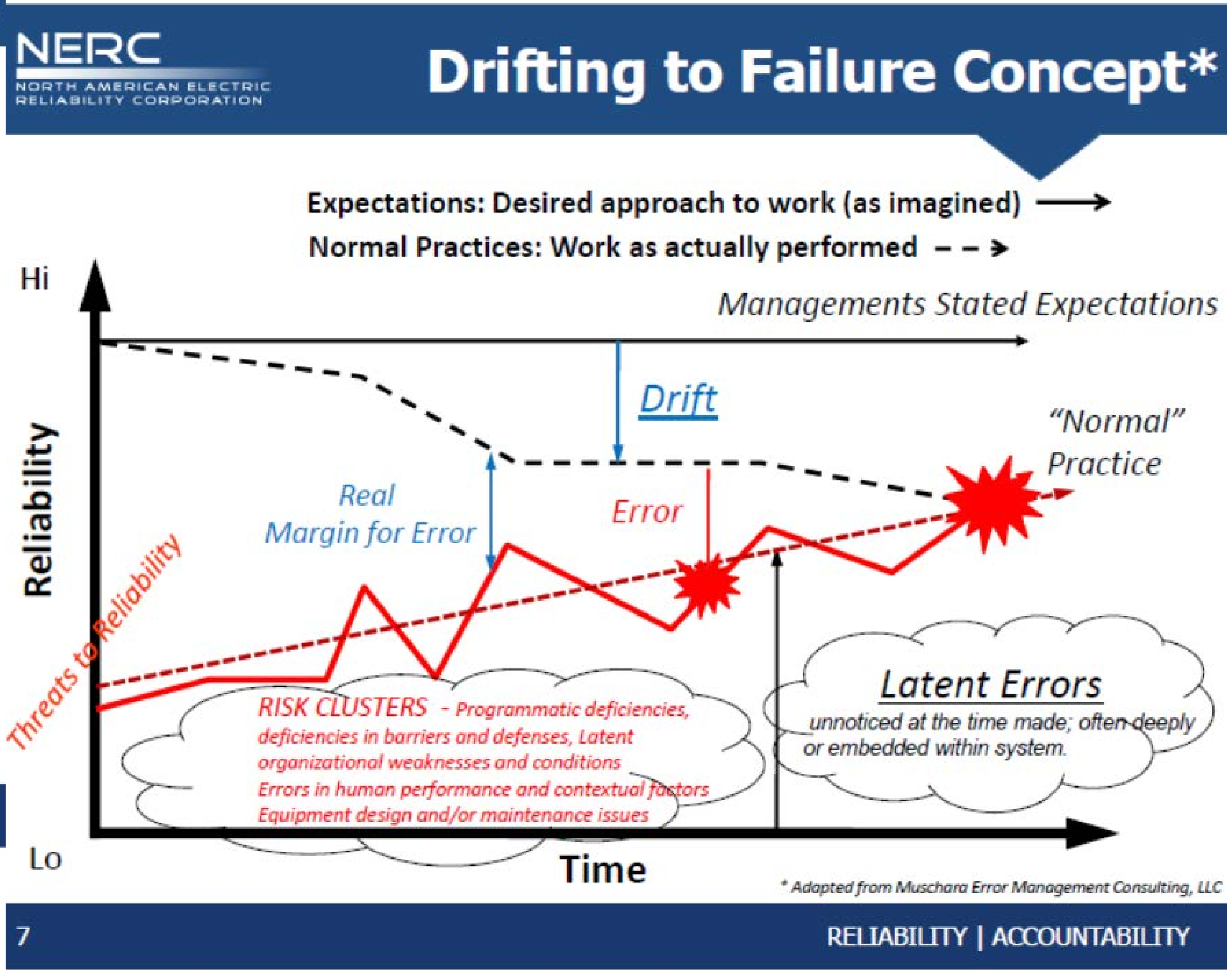
OSHA Total Recordable Case (TRC) Rate



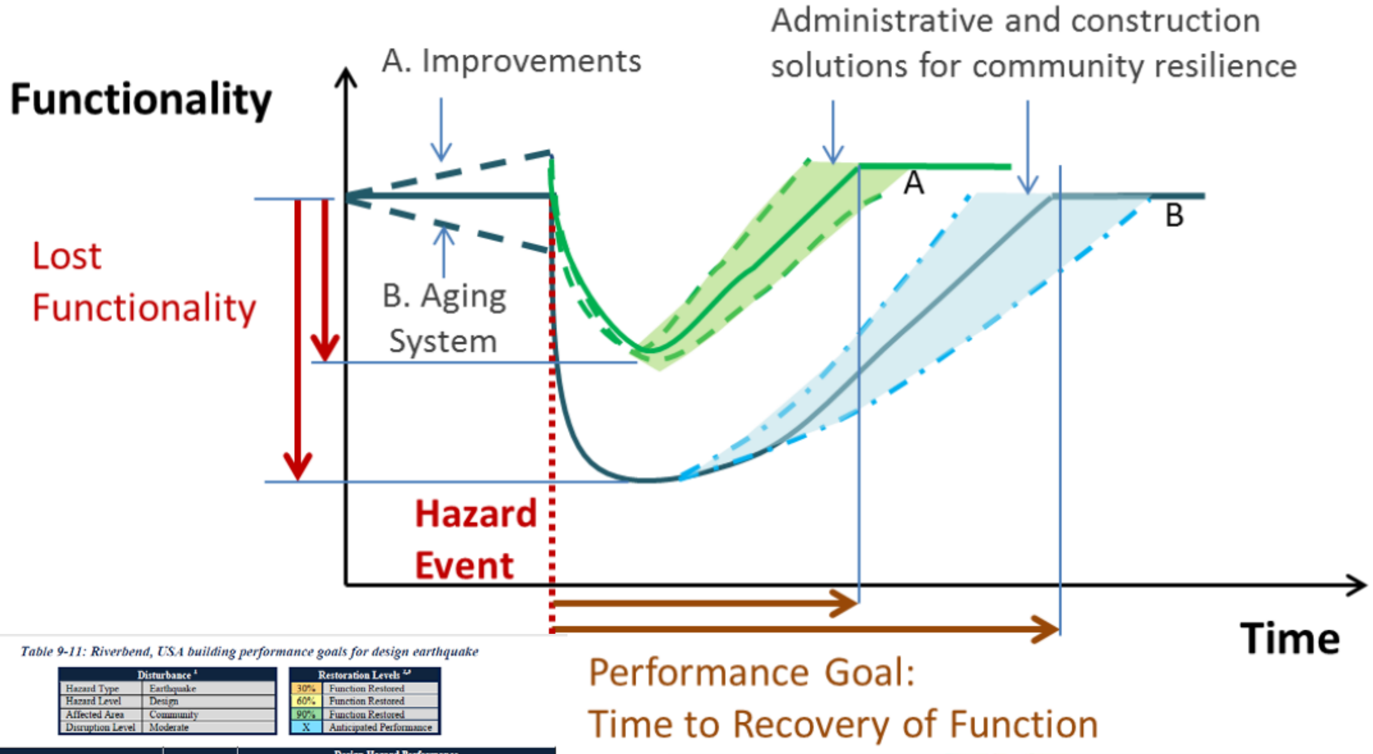


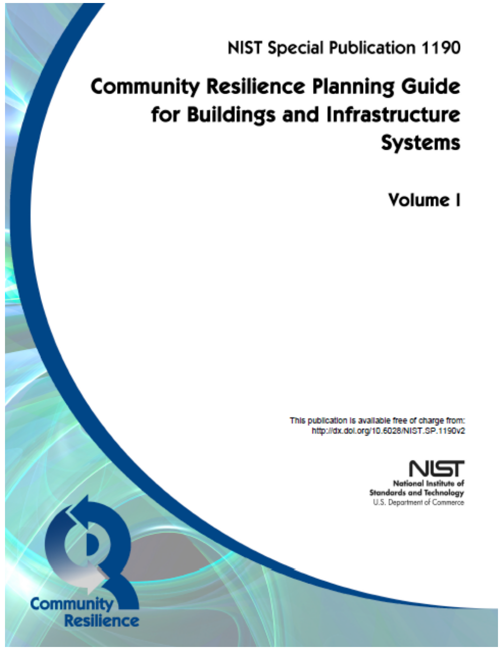
Risk Management – Reliability





Risk Management – Resilience





NIST Community Resilience Planning Guide
Oct2015

Table 9-11: Riverbend, USA building performance goals for design earthquake

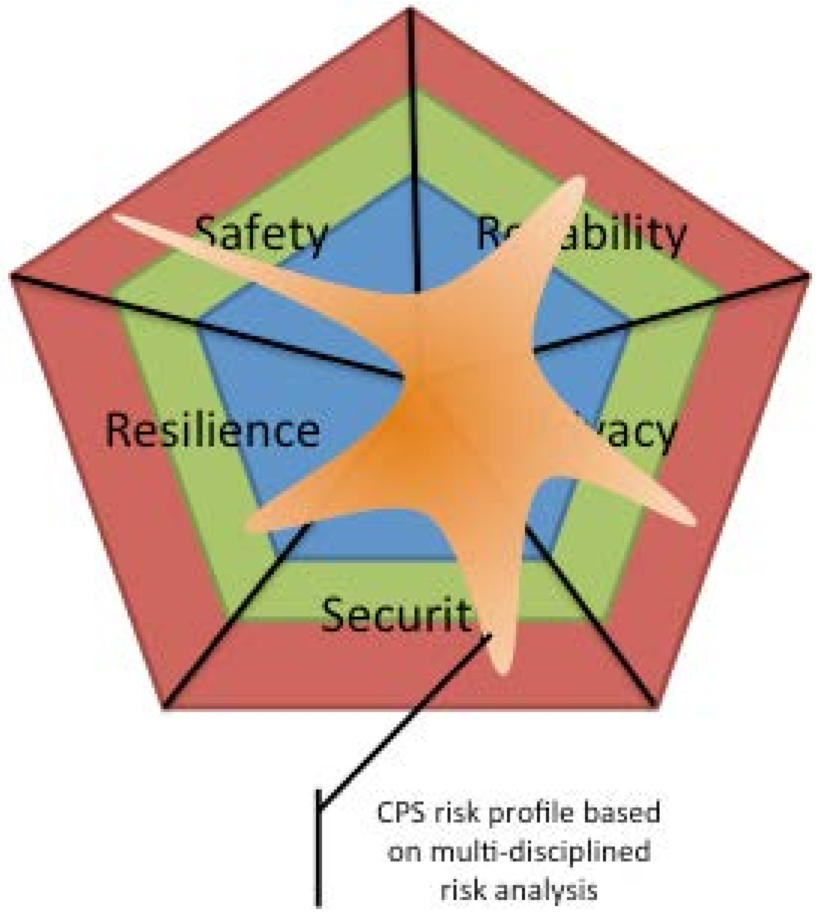
Disturbance [1]	
Hazard Type	Earthquake
Hazard Level	Design
Affected Area	Community
Disruption Level	Moderate

Restoration Levels [2,3]	
30%	Function Restored
60%	Function Restored
90%	Function Restored
X	Anticipated Performance

Building Clusters	Support Needed[4]	Design Hazard Performance								
		Phase 1 Short-Term			Phase 2 Intermediate			Phase 3 Long-Term		
		Days			Weeks			Months		
		0	1	1-3	1-4	4-8	8-12	4	4-24	24+
		Building Performance Category								
		A			B		C			D
Critical Facilities										
Emergency Operation Centers	R, S, MS	90%							X	
First Responder Facilities	R, S, MS	90%							X	
Memorial Hospital	R, S, MS	90%							X	
Non-ambulatory Occupants (prisons, nursing homes, etc.)	R, S, MS	90%							X	
National Aircraft Parts Factory (NAP)	R, S, C	90%							X	
Emergency Housing										
Temporary Emergency Shelters	R, S	30%	90%							X
Single and Multi-family Housing (Shelter in place)	R, S	60%			90%					X
Housing/Neighborhood										
Critical Retail	R, S, C		30%	60%	90%					X
Religious and Spiritual Centers	R, S			30%	60%	90%				X
Single and Multi-family Housing (Full Function)	R, S			30%		60%		90%		X
Schools	R, S			30%	60%	90%				X
Hotels & Motels	R, S, C			30%		60%	90%			X
Community Recovery										
Businesses – Manufacturing (except NAP)	R, S, C				30%	60%	90%			X
Businesses - Commodity Services	R, S, C				30%	60%		90%		X
Businesses - Service Professions	R, S, C				30%		60%		90%	X
Conference & Event Venues	R, S, C				30%		60%		90%	X

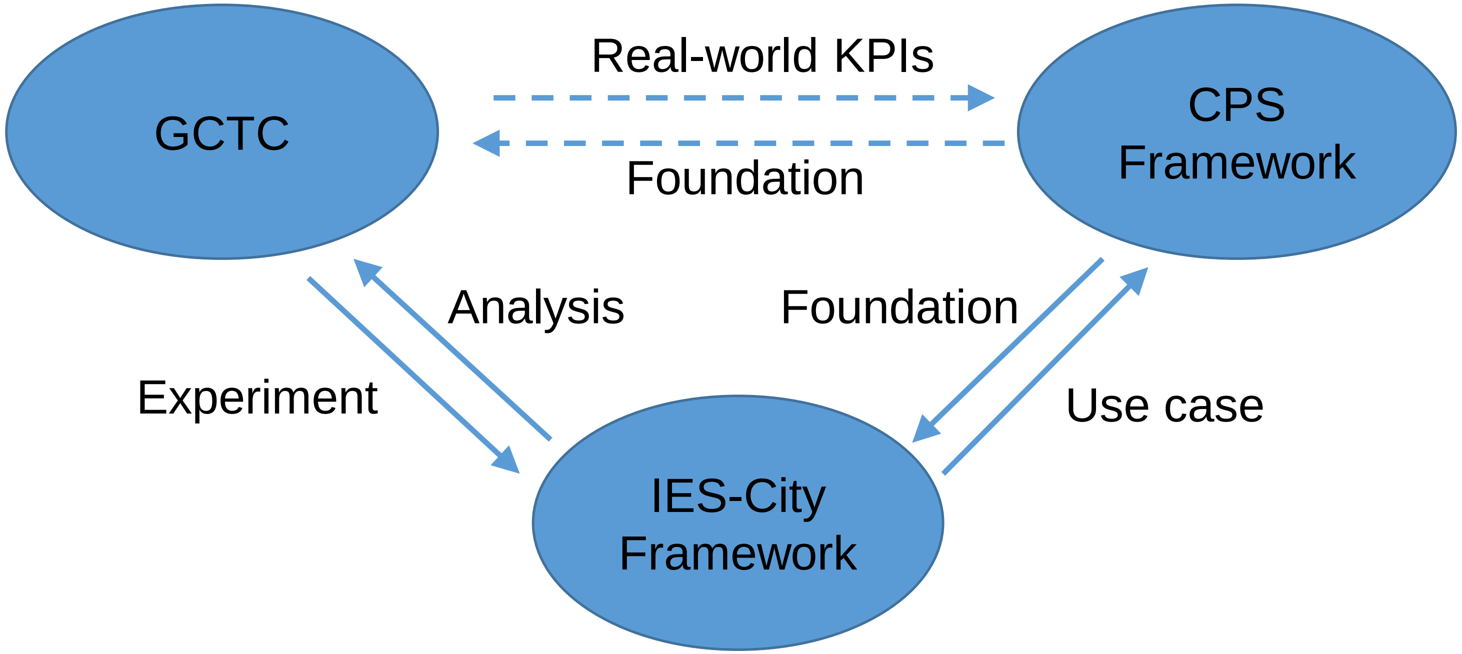
Trustworthiness Collaboration

- Original Working Group had expertise in cybersecurity and privacy
- Need to broaden expertise in resilience, reliability, safety, and physical security
- Kickoff leadership group face to face meeting
    - August 30th and 31st at NIST
    - Industry / Government / Academic involvement



Opportunity for NIST: IoT Measurement in Scale

- The issue of the IoT measurement in scale is under-addressed today. Global City Teams Challenge (GCTC) is a critical building block to enable the measurement science for real-world IoT deployments in scale.



Smart Cities and Communities

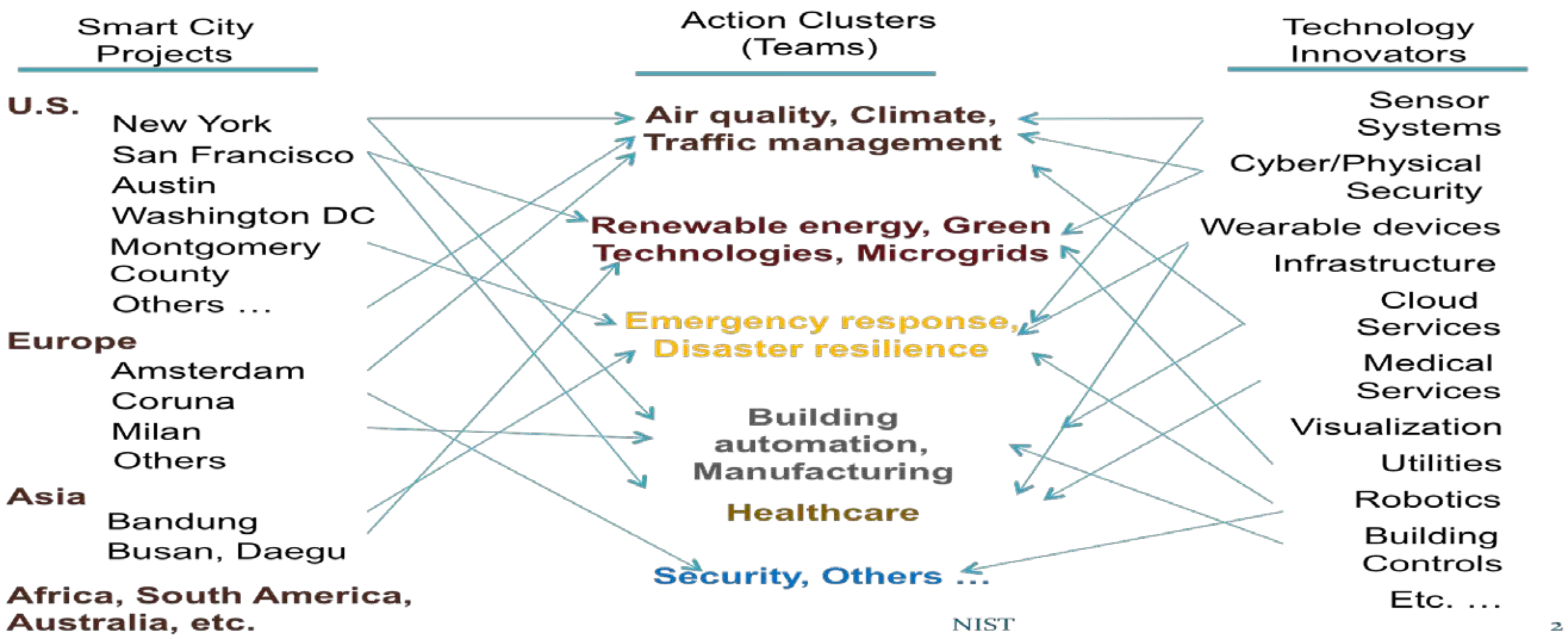
Smart City: Use smart technologies such as IoT and CPS to improve the quality of life in cities and communities

Problems of Today’s Smart City Deployments

- Many smart community efforts are one-off projects with heavy emphasis on customization and inadequate consideration for future upgradability and extensibility
- Lack of clear measurability of success impedes broader adoption of the solutions
- As a result, many Smart Cities/Communities deployments are isolated and do not enjoy the economies of scale.

Global City Teams Challenge (GCTC)

Establish and demonstrate replicable, scalable and sustainable models for collaborative incubation and deployment of interoperable, standard-based IoT solutions and demonstrate their *measurable* benefits in Smart Communities/Cities



GCTC 2016

- Currently over 100 action clusters registered
- 120+ local governments from 14 countries, and 300+ companies/organizations working to deploy replicable and interoperable solutions in multiple cities.
- At the GCTC Expo in Austin, over 90 teams gave presentations including technical architectures of the solutions. Over 2000 people attended the Expo.
- Each team creates at least one Key Performance Indicator (KPI) of the *tangible and direct* impacts to the local governments and the residents. Teams will report the feasibility and prototypes by June 2016 and the final results by June 2017.
- Suggested KPIs include:
    - Productivity/planning efficiency (e.g. frequency)
    - Environmental impacts (e.g. CO2 level)
    - Energy usage (e.g. kWh)
    - Traffic congestion (e.g. time to commute, number of cars)
    - Crime (e.g. reported number of incidents)

GCTC 2016 Expo (photo credit: NIST & US-Ignite)


GCTC 2015 Expo (photo credit: NIST & US-Ignite)

Smart City Measurement Science in GCTC

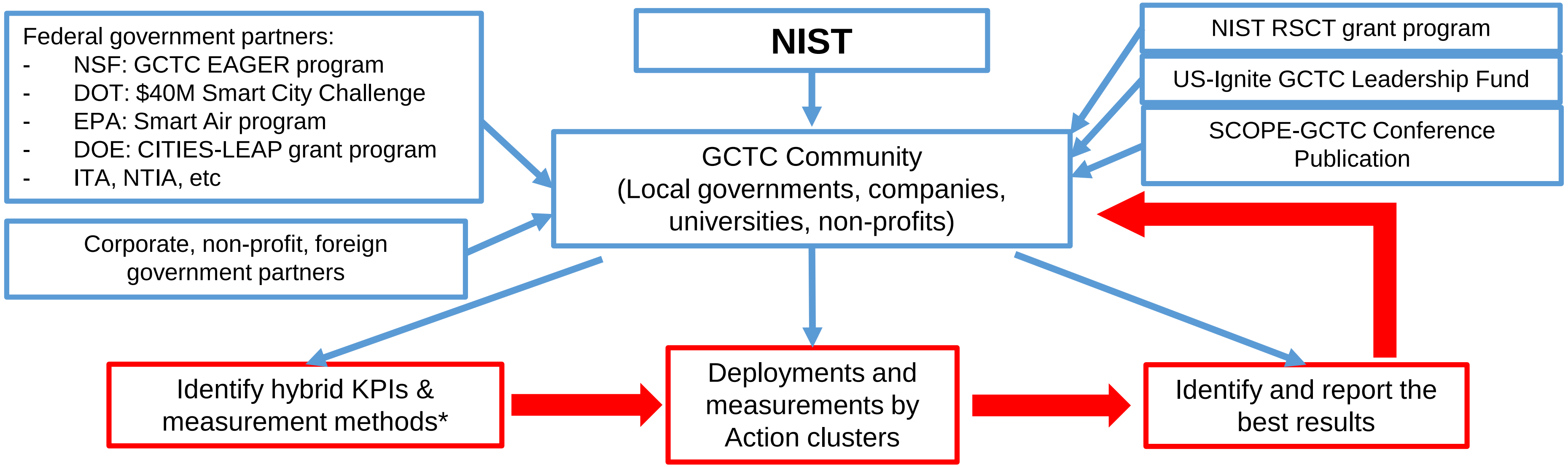
Approaches & Next Steps

- *Through community-based approach, identify quantifiable and measurable KPIs describing tangible impacts.* The KPIs will need to be selected considering the relevance and sensitivity to the impacts of the projects. Availability and measurability of data should be also considered.
- *Analyze correlations between KPIs considering the system of systems perspective and create "hybrid KPIs"* that can represent true overall impact of projects to the city government and/or to the residents.
- *Produce generalized frameworks or technical publications* to define and measure the hybrid KPIs for the projects and make them available to the community.

- Examples of Prior works of Smart City KPIs
  - ISO 37120:2014, ISO/TS 37151:2015
  - ITU-T FG-SSC: Key performance indicators definitions for smart sustainable cities
  - CITYKeys by EU
  - Smart City Cluster Collaboration, Task 4, (EU funded)
- Issues about Prior Works
  - Correlations and tradeoffs between KPIs are not well considered. Many suggested KPIs measure only a single aspect and do not represent the system of systems aspect of smart cities (e.g. air pollution reduction vs. increase of traffic congestion)
  - Many KPIs are still based on Likert scale which is qualitative and anecdotal.
  - Relevance and sensitivity of KPIs to represent the impact of projects are not well defined.

Community-based Smart City Measurement Science

Hybrid KPIs and measurement methods will be identified and applied to the participating action clusters. The results and methodologies will be made available to the community for further adoption.



Products

- Hybrid KPI research and analysis
- IES-City framework output based on GCTC super clusters
- Reports and analysis from the RSCT projects

*Prior works such as ISO/TS 37151:2015 and CITYKeys by EU can be reviewed and used as basic building blocks.

RSCT Grant Program

- Purpose: To enable cities and communities to take a lead role in the team-based GCTC efforts to advance the measurement science of replicable, standards-based smart city technologies that provide measurable performance metrics, meet the needs of cities and communities of all types and sizes, and provide platforms for entrepreneurship and innovation.
- 3 local governments, each up to $100,000
  - Clear and quantifiable performance goals for planned smart city systems and/or applications
  - Effective use of existing standards to provide for interoperability across infrastructure systems
  - The mechanisms for documenting and reporting the progress and the results for public consumption

engineering laboratory

Community Resilience Program

NIST Smart Grid
AC Meeting

July 13, 2016

Therese McAllister, PhD, PE

Program Manager

Community Resilience Group Leader

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

How is Resilience Defined?

- Resilience is defined as:
  - "the ability to *prepare for* and *adapt to* changing conditions and to *withstand* and *recover rapidly* from disruptions.
  - Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents." (PPD-21)

New Orleans Flooding in 2005 (FEMA)

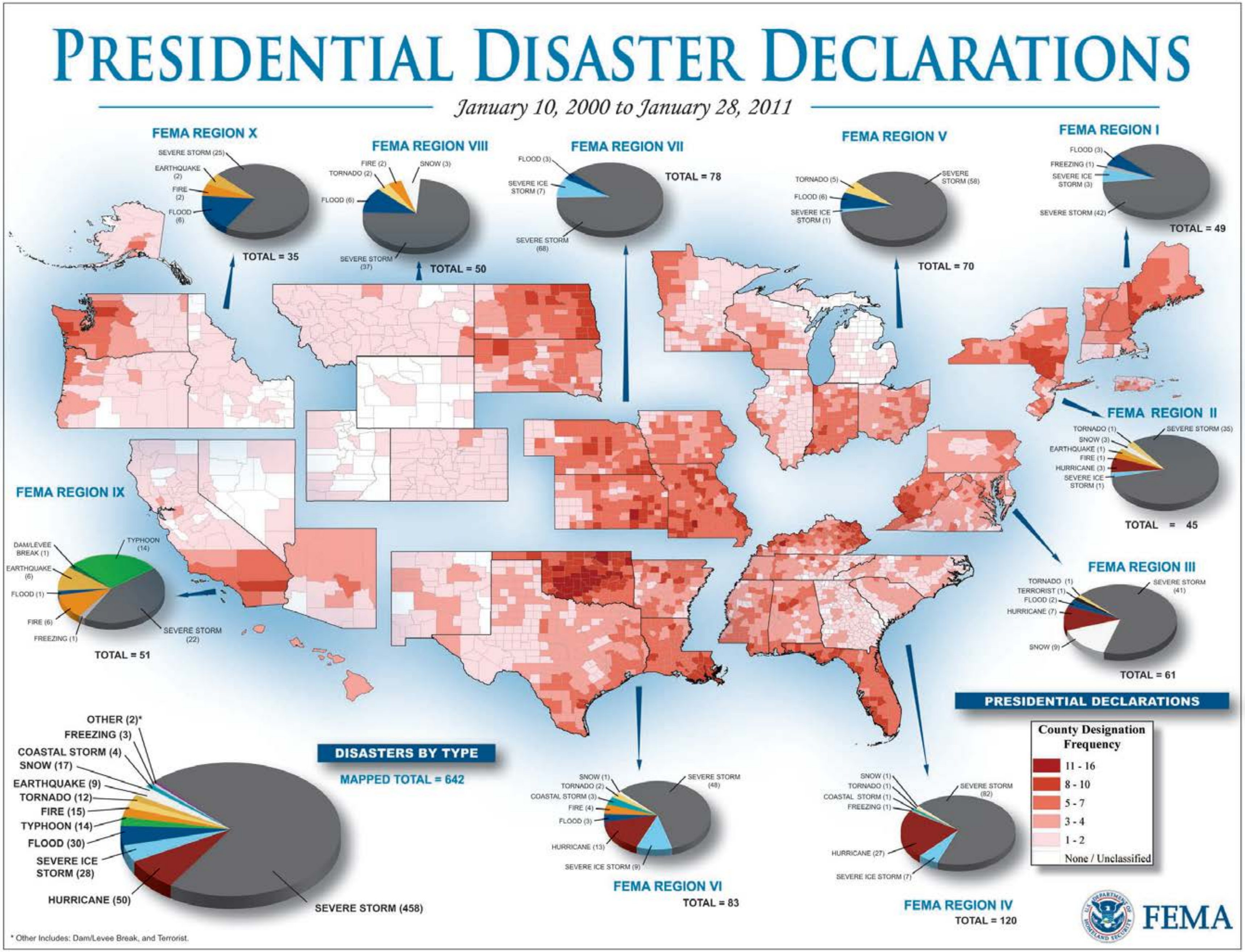
- In the context of community resilience, the emphasis is not solely on mitigating risk, but implementing measures to ensure that the community recovers to normal, or near normal function, in a reasonable timeframe.

Why Community Resilience Planning?

- All communities face potential disruption from natural, technological, and human-caused hazards.
- Disasters take a high toll in lives, livelihoods, and quality of life – the impact can be reduced by better managing risks.
- Planning and implementing *prioritized* measures can improve a community's ability to restore vital services in a timely way – and build back *better*.
- The built environment exists to serve social functions (e.g., a hospital provides healthcare). Therefore, social functions should drive the performance goals of buildings and physical infrastructure.


Cedar Rapids, Iowa, 2008 floods


Hurricane Sandy 2012



PRESIDENTIAL DISASTER DECLARATIONS
January 10, 2000 to January 28, 2011
FEMA REGION X
SEVERE STORM (25)
EARTHQUAKE (2)
FIRE (2)
FLOOD (6)
TOTAL = 35
FEMA REGION VIII
FIRE (2)
SNOW (3)
TORNADO (2)
FLOOD (6)
SEVERE STORM (37)
TOTAL = 50
FEMA REGION VII
FLOOD (3)
SEVERE ICE STORM (7)
SEVERE STORM (68)
TOTAL = 78
FEMA REGION V
TORNADO (5)
FLOOD (6)
SEVERE ICE STORM (1)
SEVERE STORM (58)
TOTAL = 70
FEMA REGION I
FLOOD (3)
FREEZING (1)
SEVERE ICE STORM (3)
SEVERE STORM (42)
TOTAL = 49
FEMA REGION II
TORNADO (1)
SNOW (3)
EARTHQUAKE (1)
FIRE (1)
HURRICANE (3)
SEVERE ICE STORM (1)
SEVERE STORM (35)
TOTAL = 45
FEMA REGION III
TORNADO (1)
TERRORIST (1)
FLOOD (2)
HURRICANE (7)
SNOW (9)
SEVERE STORM (41)
TOTAL = 61
FEMA REGION IX
DAM/LEVEE BREAK (1)
EARTHQUAKE (6)
FLOOD (1)
FIRE (6)
FREEZING (1)
TYPHOON (14)
SEVERE STORM (22)
TOTAL = 51
FEMA REGION VI
SNOW (1)
TORNADO (2)
COASTAL STORM (3)
FIRE (4)
FLOOD (3)
HURRICANE (13)
SEVERE ICE STORM (9)
SEVERE STORM (48)
TOTAL = 83
FEMA REGION IV
SNOW (1)
TORNADO (1)
COASTAL STORM (1)
FREEZING (1)
HURRICANE (27)
SEVERE ICE STORM (7)
SEVERE STORM (82)
TOTAL = 120
DISASTERS BY TYPE
MAPPED TOTAL = 642
OTHER (2)*
FREEZING (3)
COASTAL STORM (4)
SNOW (17)
EARTHQUAKE (9)
TORNADO (12)
FIRE (15)
TYPHOON (14)
FLOOD (30)
SEVERE ICE STORM (28)
HURRICANE (50)
SEVERE STORM (458)
PRESIDENTIAL DECLARATIONS
County Designation Frequency
11 - 16
8 - 10
5 - 7
3 - 4
1 - 2
None / Unclassified
FEMA
* Other Includes: Dam/Levee Break, and Terrorist.

Community Resilience Program Elements

- Outreach and Engagement
  - Community Resilience Guides
  - Community Resilience Panel
- Science Based Tools and Metrics
  - NIST Research
  - Center of Excellence

Outreach and Engagement Goals

- The long-term goal of the NIST Community Resilience Program is to improve recovery and minimize disruption to community functions following hazard events.
- The Guide offers a first step toward achieving that goal, by providing a uniform process for developing a prioritized resilience plan that is integrated with existing comprehensive plans, economic development plans, and hazard mitigation plans.
- To achieve the long-term goal, NIST will work toward achieving the following near term goals:
  - 1. Adoption and implementation by early adopter communities
  - 2. Promotion or use of the Guide by existing federal and state government programs and agencies.
  - 3. Use of the Guide as a basis or reference in other federal or state guidance and tools.

NIST Planning Guide Basics

- A *practical, flexible methodology* to set priorities, allocate resources, and manage risks…improving resilience.
- Offers a way to turn resilience concepts action:
  some actions can be taken in the near-term,
  others may take years or even decades to put in place.
- Developed with private and public sector experts, the Guide can help communities to:
  - Set goals and develop resilience plans for both public and private systems
  - Identify collaborative plans and actions to improve system and community resilience.

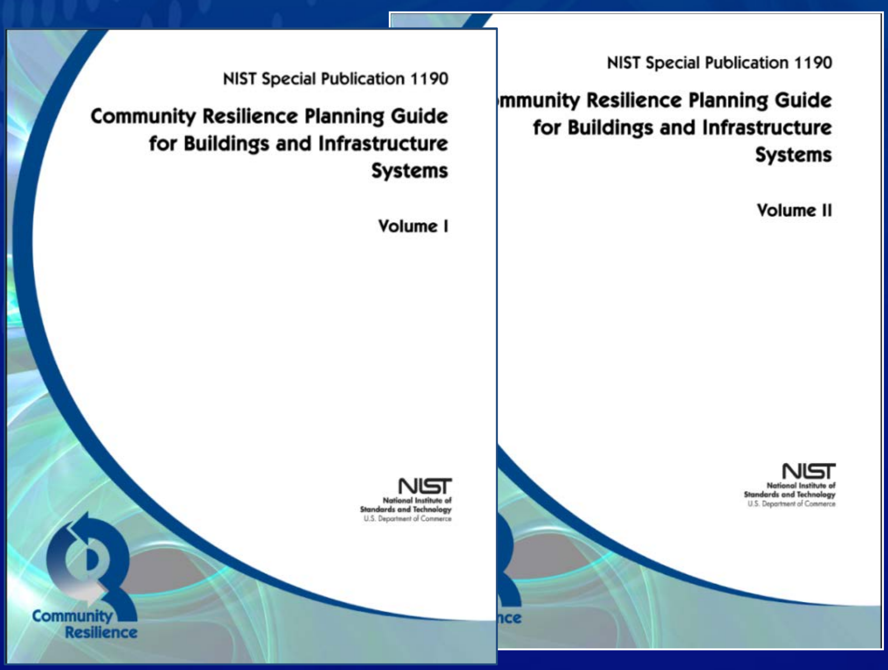
Guide Development Process

- Extensive public and private sector input from organizations and individuals

Community Resilience Planning Guide for Buildings and Infrastructure Systems

Volume 1 - Methodology

- Introduction
- 6 Step Methodology
- Planning Example – Riverbend
- Glossary and Acronyms



Volume 2 - Reference

- Social Community
- Dependencies and Cascading Effects
- Buildings
- Transportation Systems
- Energy Systems
- Communications Systems
- Water & Wastewater Systems
- Community Resilience Metrics

- http://www.nist.gov/el/resilience/

6-Step Guide for Community Resilience

SIX-STEP GUIDE TO PLANNING FOR COMMUNITY RESILIENCE

1. FORM A COLLABORATIVE PLANNING TEAM
- Identify leader
- Identify team members
- Identify key stakeholders

2. UNDERSTAND THE SITUATION
Social Dimensions
- Characterize social functions & dependencies
- Identify support by built environment
- Identify key contacts

Built Environment
- Identify and characterize built environment
- Identify key contacts
- Identify existing community plans

Link Social Functions & Built Environment
- Define clusters

3. DETERMINE GOALS & OBJECTIVES
- Establish long-term community goals
- Establish performance goals
- Define community hazards
- Determine anticipated performance
- Summarize results

4. PLAN DEVELOPMENT
- Evaluate gaps
- Identify solutions
- Develop implementation strategy

5. PLAN PREPARATION, REVIEW, AND APPROVAL
- Document plan and strategy
- Obtain feedback and approval
- Finalize and approve plan

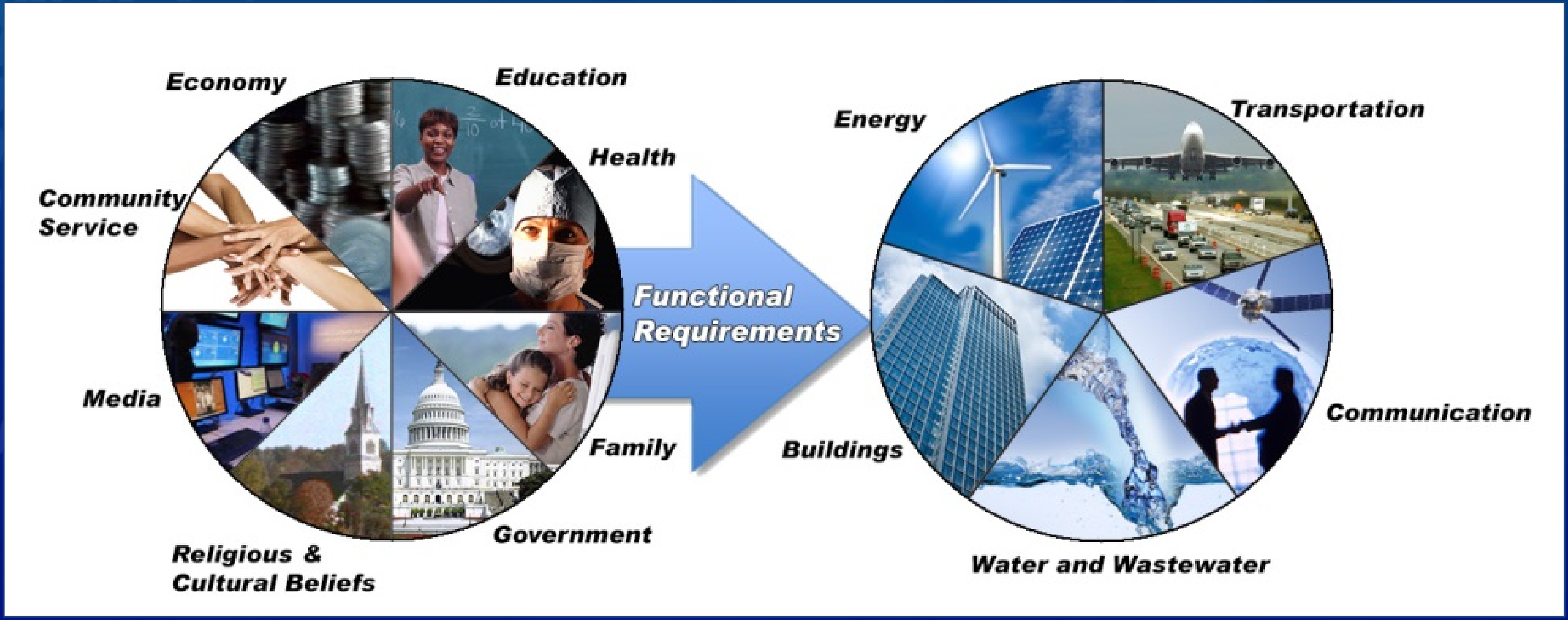
6. PLAN IMPLEMENTATION AND MAINTENANCE
- Execute approved solutions
- Evaluate and update
- Modify strategy as needed

Community Resilience

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

Key Concept: Functional Requirements

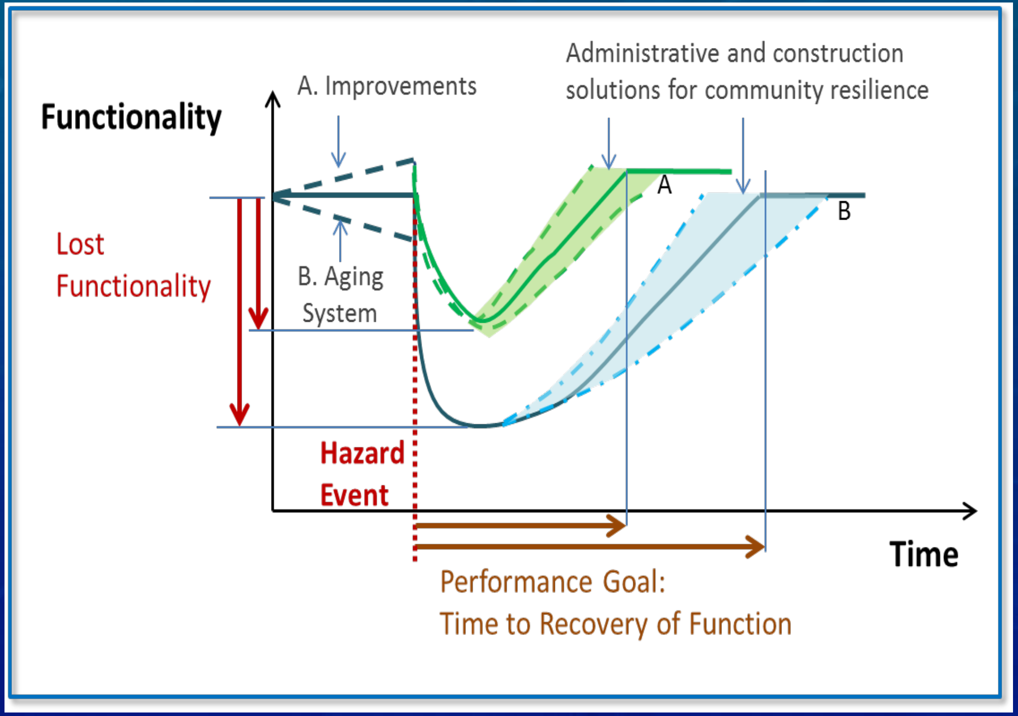
- Infrastructure systems and buildings play a key role in protecting citizens, and supporting the immediate response and recovery of a community following a disruptive event.



Key Concepts for Infrastructure Resilience

- Context
  - What is the role of the infrastructure in the community, including its recovery?
- Functionality
  - Time to recovery of infrastructure function should be tied to community social needs
- Dependencies
  - No system is an island

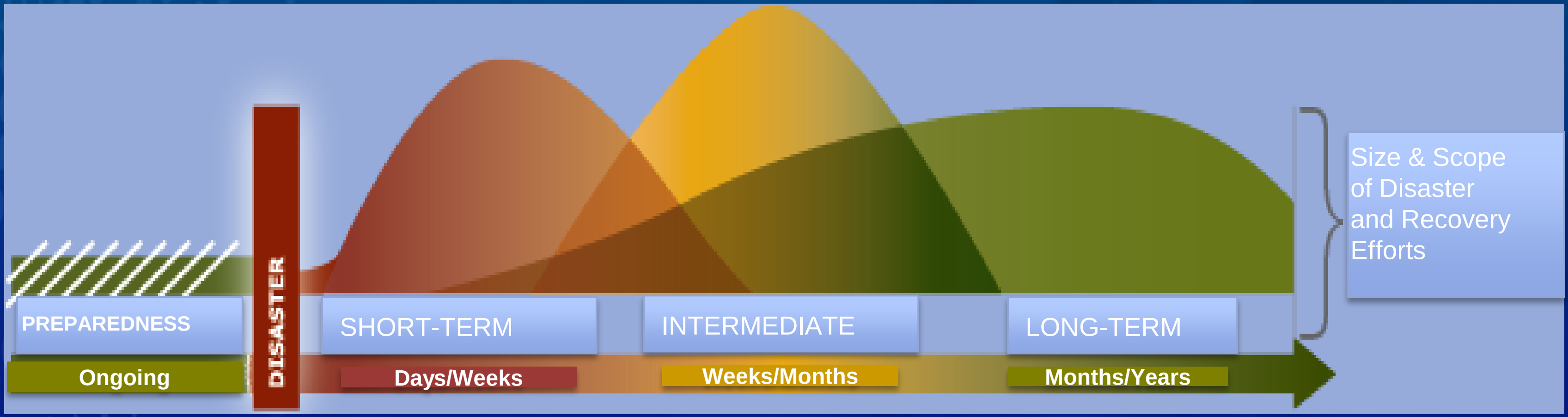
Key Concept: Recovery of Function



Resilience can be expressed simply in terms of the ***time to recover functionality*** following a disruptive hazard event.

Recovery of Built Environment Function

Organize around restoring functionality over time



When is each system needed for recovery?

Example Summary Resilience Table

Infrastructure	Recovery Time								
		1	1-3	1-4	4-8	8-12	4	4-24	24+
Critical Facilities									
	90%							X	
		90%	X						
		90%	X						
			90%		X				
Wastewater				90%				X	
		90%		X					
Emergency Housing									
Buildings									
Transportation									
Energy									
Water					X				
Waste Water									
Communication					X				
Housing/Neighborhoods									
Buildings						90%			X
Transportation			90%	X					
Energy			90%	X					
Water				90%				X	
Waste Water					90%			X	
Communication				90%			X		
Community Recovery									
Buildings								90%	X
Transportation				90%	X				
Energy			90%	X					
Water				90%				X	
Waste Water							90%	X	
Communication				90%			X		

Desired Performance

Anticipated Performance



Superstorm Sandy

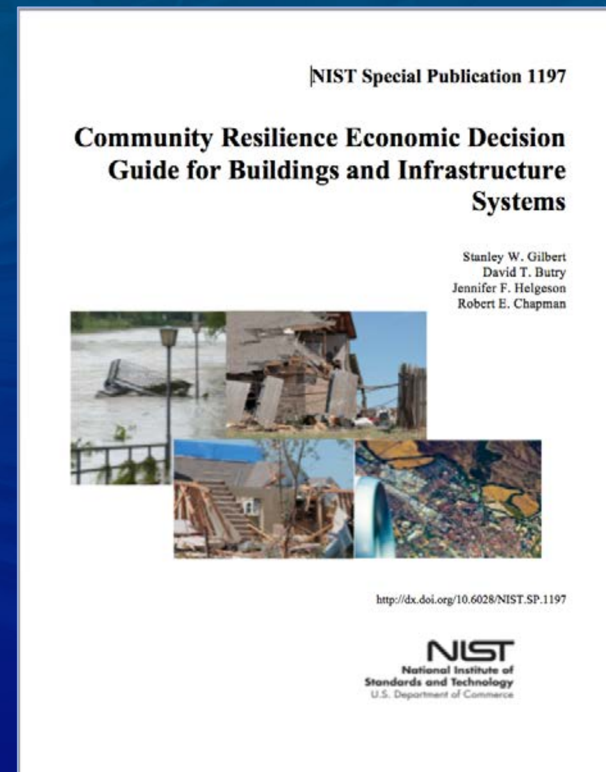
Guide Use by Communities

- “The power of the NIST approach to community resilience,” stated the county report, “is that these time-to-recovery goals for facilities are not considered in isolation. The infrastructure that supports the facilities must also meet the goal.”
- The Planning Guide is being used by municipalities, counties, states, and other communities across the US.

A damaged roadway after the September 2013 flooding in Colorado. The disaster spurred Boulder County communities to develop a resilience design performance standard largely based on NIST’s Community Resilience Planning Guide.

Economic Decision Guide (EDG)

- Provides a standard methodology for evaluating investment decisions for communities resilience
- Designed for use with NIST's Planning Guide
  - Provides a mechanism to evaluate and <u>prioritize </u>resilience actions
- Frames the economic decision process
  - Identifies and compares resilience-related benefits & costs
    - Across competing alternatives
    - Versus the status quo (do-nothing)


NIST Special Publication 1197

Community Resilience Economic Decision Guide for Buildings and Infrastructure Systems

Stanley W. Gilbert
David T. Butry
Jennifer F. Helgeson
Robert E. Chapman

http://dx.doi.org/10.6028/NIST.SP.1197

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Community Resilience Panel

- **Mission**

  Reduce barriers to achieving community resilience by promoting collaboration among stakeholders to improve the resilience of buildings, infrastructure, and social systems upon which communities rely.

- **Goals**
  - Engage and connect community and cross-sector stakeholders
  - Identify policy and standards gaps and barriers
  - Raise awareness of dependencies & cascading effects
  - Contribute to community resilience documents
  - Develop/maintain a Resilience Knowledge Base

- **Next Meeting**
  - September 21-22, 2016
  - Denver area

Federal Co-Sponsors

Disaster Resilience Fellows

Community Resilience Planning

- Chris Poland, Chris D. Poland Consulting Engineer
- Donna Boyce, Solix Inc

Emergency Planning and Response

- *Jay Wilson, Hazard Mitigation Program Coordinator for Clackamas County*

Business Continuity Planning

- George B. Huff Jr., The Continuity Project

Societal Dimensions of Disasters

- Liesel Ritchie, University of Colorado Natural Hazards Center

Electrical Power Infrastructure

- Stuart McCafferty, Hitachi Consulting
- Erich Gunther, EnerNex

Transportation Infrastructure

- Joseph Englot, HNTB
- Theodore Zoli, HNTB

Water Infrastructure

- *Donald Ballantyne, Ballantyne Consulting LLC*
- *Kevin Morley, AWWA*

Communication Infrastructure

- Steve Poupos, AT&T's Director of Global Network Operations

Research Goals

- The long-term goal of the NIST Community Resilience Program is to improve recovery and minimize disruption to community functions following hazard events.
- NIST and the CoE will work toward achieving the following goals:
  - 1. Develop and validate a community-scale modeling environment for integrated physical, social, and economic systems that can simulate dependencies and recovery of functions to support decision making.
  - 2. Develop and validate assessment methods for community resilience, including science-based indicators, metrics, and tools.

NIST R&D for Science Based Tools

Systems methods and models

- Simulate the effects of physical system (buildings and infrastructure) disruptions on the social and economic functions.
- Develop methodologies, metrics, and tools to model community level performance and recovery of physical and social systems, including dependencies and uncertainties

Assessment of community resilience

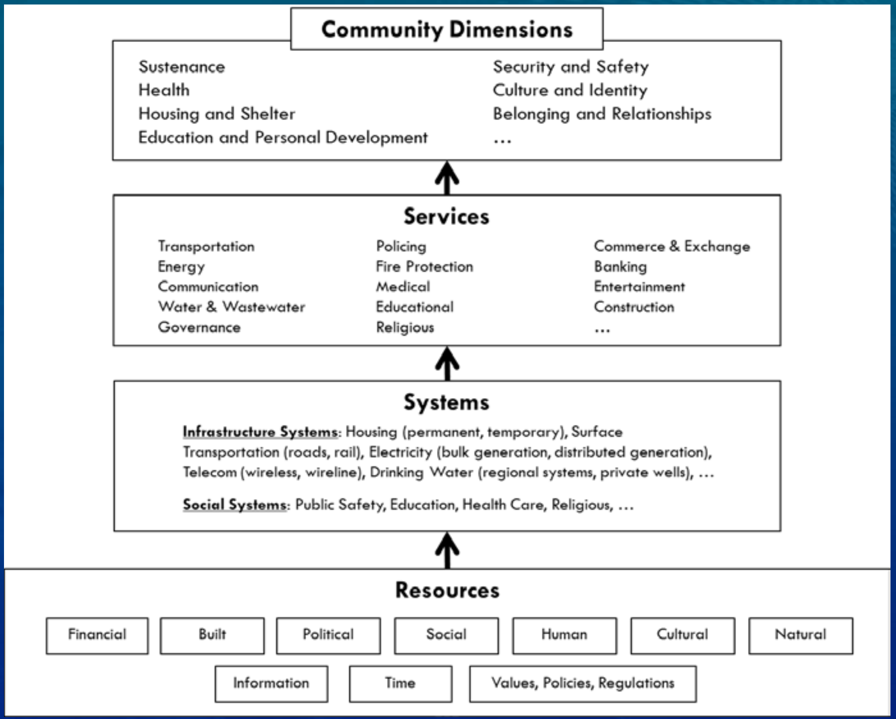
- Identify performance goals and metrics for the built environment based on the social systems and needs in the community
- Develop tools and metrics to assess resilience at the community scale that account for physical, social, and economic systems, and their dependencies.

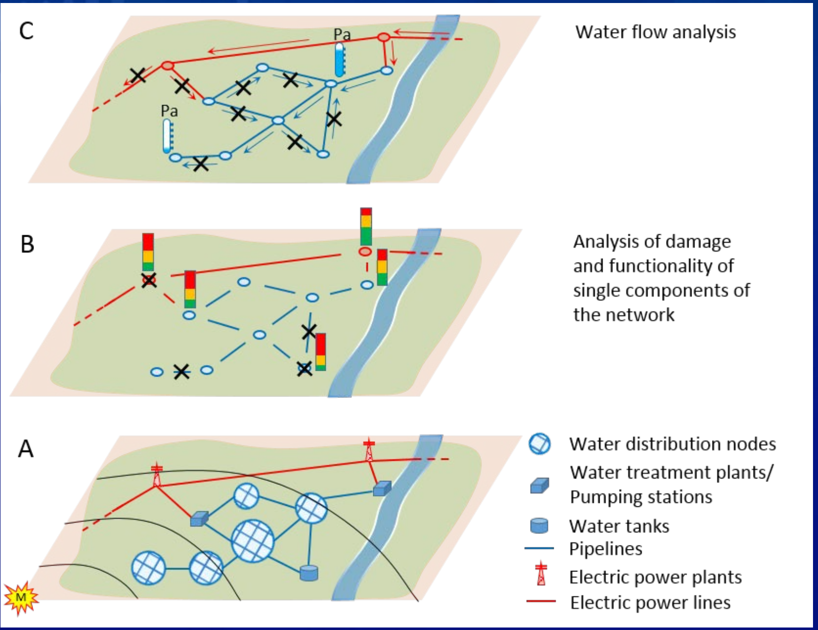
Economic methodology to support decision making

- Develop methodologies, metrics, and tools for resilience benefits and co-benefits for investments

Community Resilience Research

- Community Assessment Methods Research
  - Provide a technical foundation for assessing resilience at the community scale
  - Developed conceptual framework
  - Expanding to address recovery of community services and functions





- Modeling of Community Systems
  - Collaborating with the Center for Risk-Based Community Resilience Planning
  - Developing probabilistic damage and service models of buildings, water, power, & transportation systems

NIST-Funded Center of Excellence

NIST Center of Excellence for Risk-Based Community Resilience Planning

- Awarded to 10 institution team led by Colorado State University.
- $4M/year program funded through a cooperative agreement.

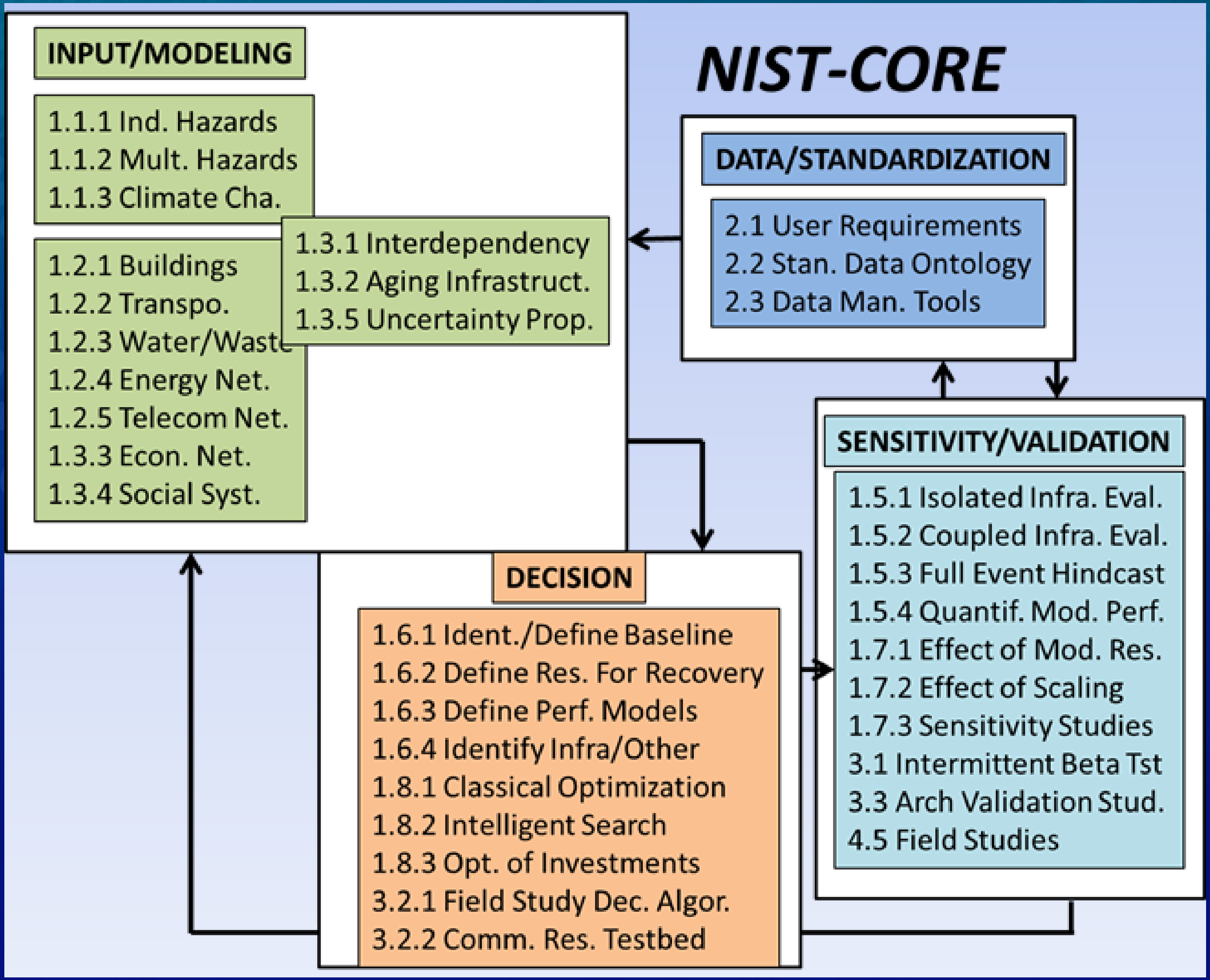
Objectives

- – Develop an integrated, multi-scale, computational environment with systems-level models
- – Develop data architectures and management tools to enable use of multi-disciplinary data
- – Conduct studies to validate models and data tools for a variety of hazard events including:
  - Tornado, hurricane, earthquake, flood, wildland-urban interface (WUI) fire
  - Effects of climate change and aging infrastructure

Envisioned products and end-users at 5 years

- Modeling environment for researchers
- Available incremental tools and metrics for community planners, designers, analysts, etc.

CoE Tasks



NIST-CORE
INPUT/MODELING
1.1.1 Ind. Hazards
1.1.2 Mult. Hazards
1.1.3 Climate Cha.
1.2.1 Buildings
1.2.2 Transpo.
1.2.3 Water/Waste
1.2.4 Energy Net.
1.2.5 Telecom Net.
1.3.3 Econ. Net.
1.3.4 Social Syst.
1.3.1 Interdependency
1.3.2 Aging Infrastruct.
1.3.5 Uncertainty Prop.
DATA/STANDARDIZATION
2.1 User Requirements
2.2 Stan. Data Ontology
2.3 Data Man. Tools
SENSITIVITY/VALIDATION
1.5.1 Isolated Infra. Eval.
1.5.2 Coupled Infra. Eval.
1.5.3 Full Event Hindcast
1.5.4 Quantif. Mod. Perf.
1.7.1 Effect of Mod. Res.
1.7.2 Effect of Scaling
1.7.3 Sensitivity Studies
3.1 Intermittent Beta Tst
3.3 Arch Validation Stud.
4.5 Field Studies
DECISION
1.6.1 Ident./Define Baseline
1.6.2 Define Res. For Recovery
1.6.3 Define Perf. Models
1.6.4 Identify Infra/Other
1.8.1 Classical Optimization
1.8.2 Intelligent Search
1.8.3 Opt. of Investments
3.2.1 Field Study Dec. Algor.
3.2.2 Comm. Res. Testbed


Steve Zumwalt, FEMA

THANK YOU