Opening Remarks

Cybersecurity in Cyber-Physical Systems Workshop
hosted by
NIST Information Technology Laboratory
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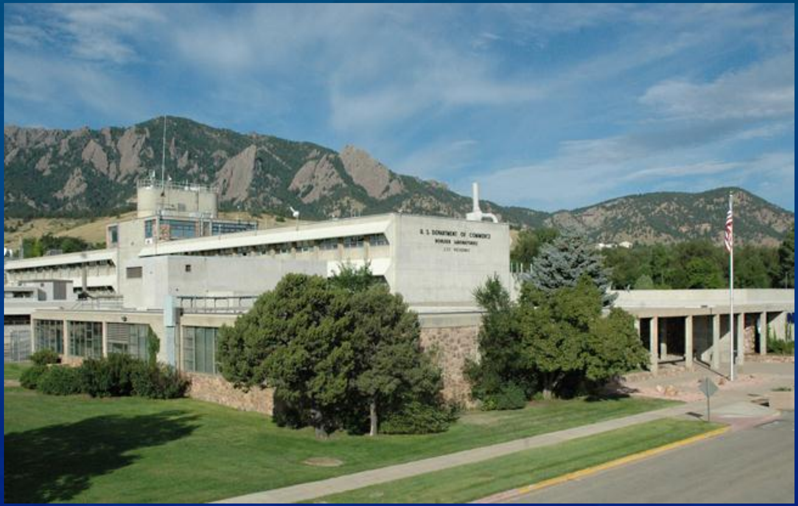
NIST At A Glance

Gaithersburg, MD

- NIST Research Laboratories
- Manufacturing Extension Partnership
- Baldrige Performance Excellence Award
- Technology Innovation Program

Boulder, CO



~ 2,900 employees

~ 2,600 associates and facility users

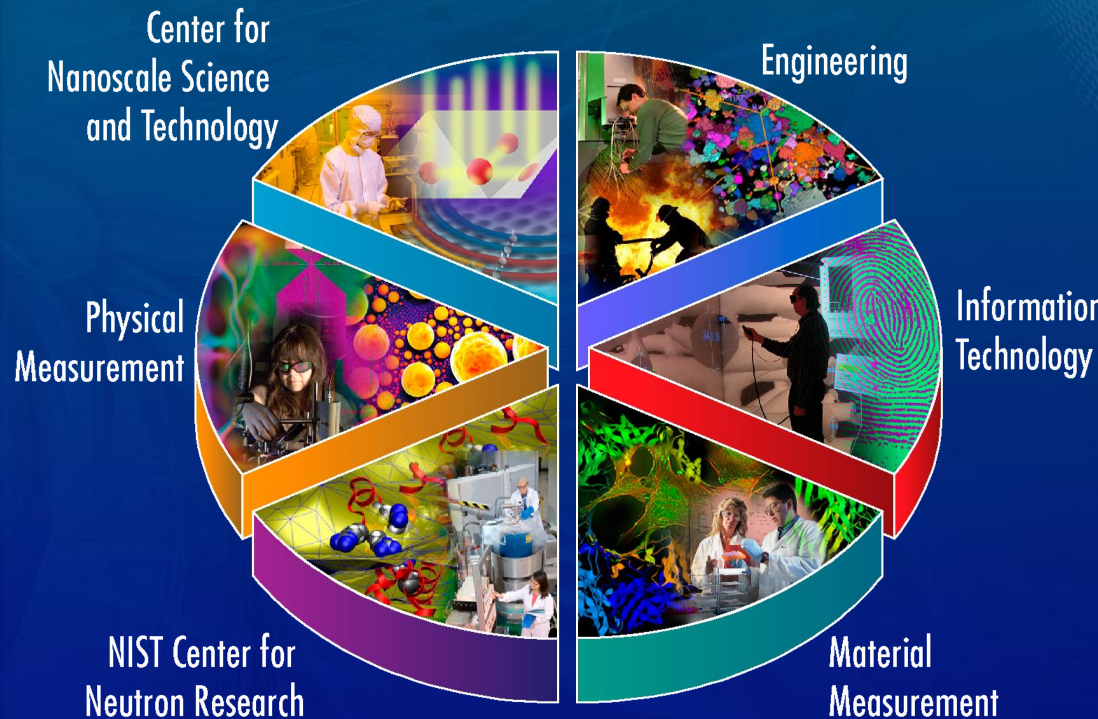
~ 1,600 field staff in partner organizations

~ 400 NIST staff serving on 1,000 national and international standards committees

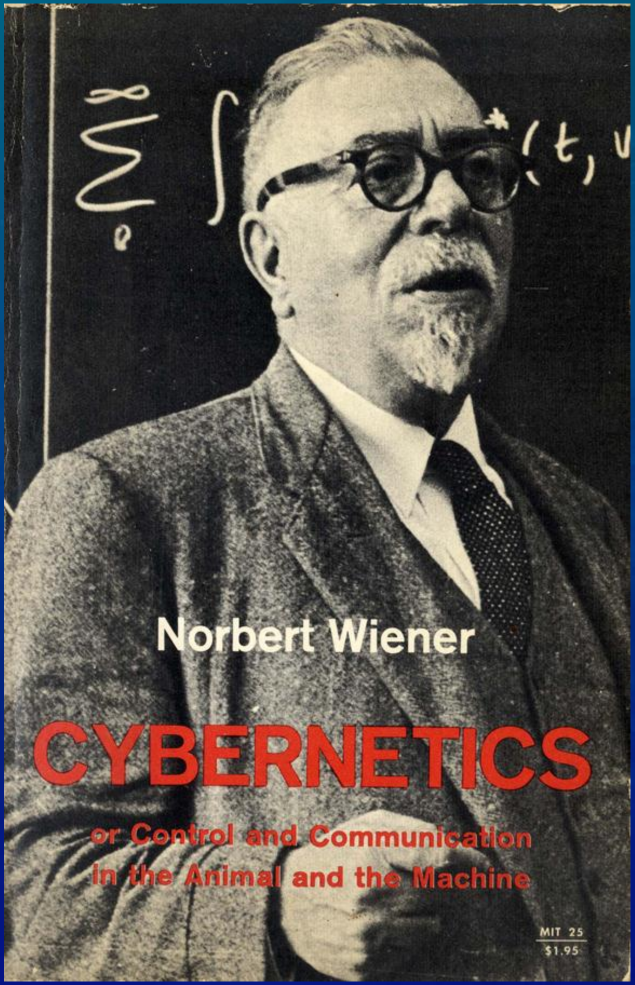
The NIST Laboratories

NIST's work enables
- Advancing manufacturing and services
- Helping ensure fair trade
- Improving public safety and security
- Improving quality of life

NIST works with
- Industry
- Academia
- Other agencies
- Government agencies
- Measurement laboratories
- Standards organizations

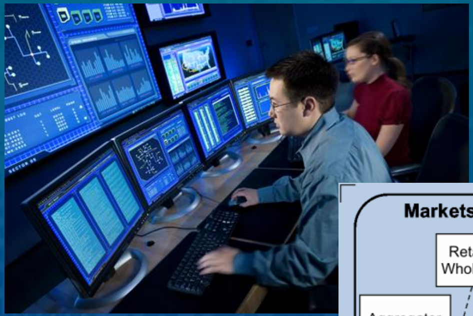


Providing measurement solutions for industry and the Nation

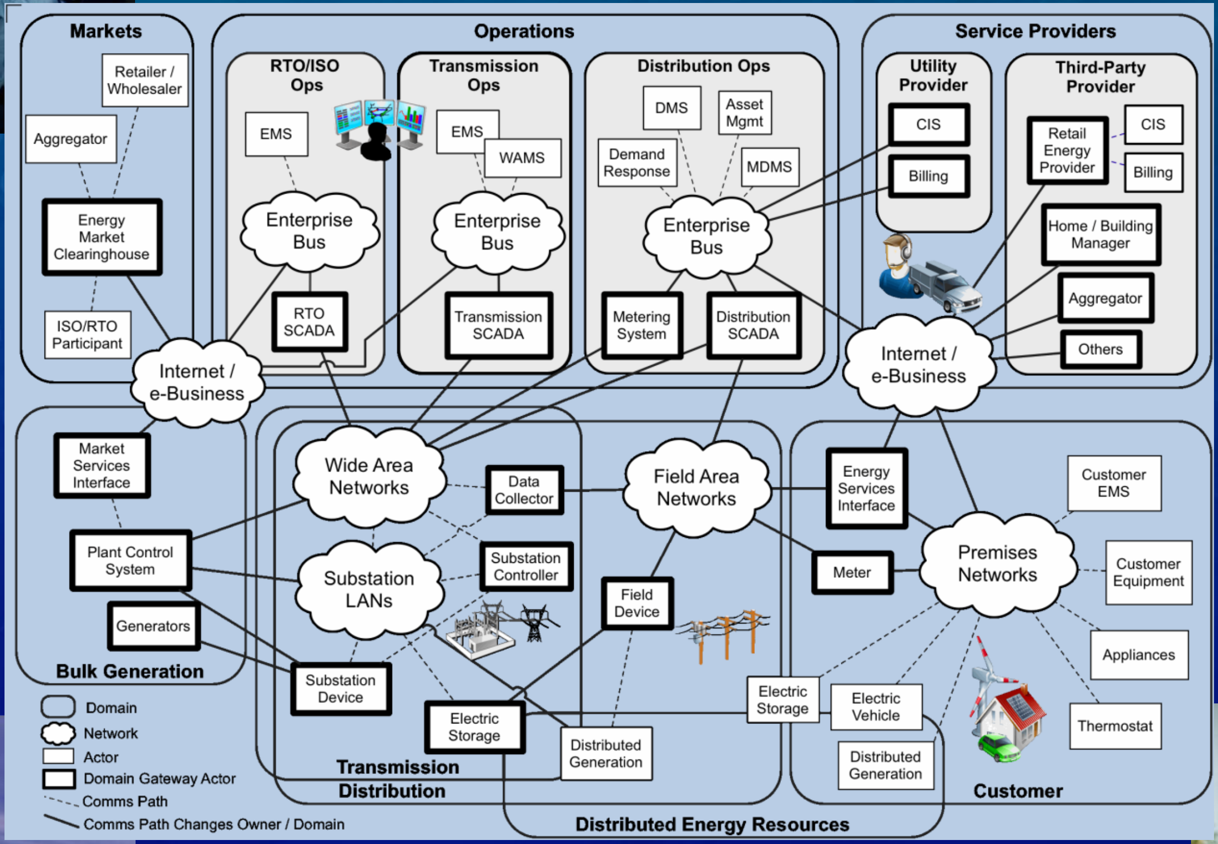


Norbert Wiener. *Cybernetics; or Control and Communication in the Animal and the Machine* (MIT Press, 1961)

Smart Grid: An Example of a CPS



NIST Smart Grid Reference Model



Smart Manufacturing: Another CPS Application

Smart Manufacturing refers to **manufacturing production systems at the equipment, factory, and enterprise levels** that integrate cyber and physical systems by combining:

- **smart operating systems** to **monitor, control, and optimize performance**
- **systems engineering-based architectures and standards,** and
- **embedded and/or distributed sensing, computing, communications, actuation, and control technologies**

to enable **innovative production**, **products**, and/or **systems of products** that enhance ***economic and sustainability performance***

Definition of Cyber-Physical Systems

Function:

Cyber physical systems are hybrid networked cyber and engineered physical elements co-designed to create adaptive and predictive systems for enhanced performance*

Essential Characteristics:

- Co-design treats cyber, engineered, and human elements as integral components of a functional whole system to create synergy and enable desired, emergent properties
- Integration of deep physics-based and digital world models provides learning and predictive capabilities for decision support (e.g., diagnostics, prognostics) and autonomous function
- Systems engineering-based architectures and standards provide for modularity and composability for customization, systems of products, and complex or dynamic applications
- Reciprocal feedback loops between computational elements and distributed sensing/actuation and monitoring/control elements enables adaptive multi-objective performance
- Networked cyber components provide a basis for scalability, complexity management, and resilience

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*Performance metrics include safety and security, reliability, agility and stability, efficiency and sustainability, privacy

CPS Application Sectors and Benefits

Application Sectors:

- **Manufacturing** (includes smart production equipment, processes, automation, control, and networks; new product design)
- **Transportation** (includes intelligent vehicles and traffic control)
- **Infrastructure** (includes smart utility grids and smart buildings/structures)
- **Health Care** (includes body area networks and assistive systems)
- **Emergency Response** (includes detection and surveillance systems, communication networks, and emergency response equipment)
- **Warfighting** (includes soldier equipment systems, weapons systems and systems of systems, logistics systems)

Benefits:

- Improved **quality of life** and **economic security** through **innovative functions, production, products,** and/or **systems of products**

NIST CPS Context

- Growing demands on NIST for standards associated with smart systems applications
  - Smart Buildings, Smart Grid and Infrastructure, Smart Manufacturing, Smart Health Care, Smart Transportation, …
- NIST has responded with programs in individual domain areas
- Significant crosscutting technology gaps and fundamental research challenges exist
- Potential impact on manufacturing: Innovative new classes of manufactured products, systems of products, and production systems

CPS Platform Technology Gaps and R&D Grand Challenges

- **Platform Technology Gaps** (Systems-Engineering Based Architectures and Standards)
  - Modularity and composability
  - Deep-physics and digital world model integration
  - Control, communications, and interoperability (adaptive and predictive; time synchronization)
  - Cyber-security
  - Scalability, complexity management, and resilience (integration with legacy systems)
  - Wireless sensing and actuation
  - Validation and verification; assurance and certification (software, controls, system)
- **R&D Grand Challenges**
  - Co-designing hybrid networked systems with integrated cyber, engineered, and human elements
  - Synthesizing and evolving complex, dynamic systems with predictable behavior (diagnostics, prognostics); anticipating emergent behaviors arising from interactions
  - Multi-scale, multi-physics modeling across discrete and continuous domains
  - Incorporating uncertainty and risk into reasoning and decision-making
  - Modeling and defining levels of autonomy and optimizing role of the human
  - Enabling education and workforce development; technology transfer

NIST CPS Actions

- **NIST CPS Working Group (EL, ITL, SCO, OLES; January 2011)**
- **Cooperative Agreement with UMD for CPS research (Kick-off December 2011)**
  - Book assessing state-of-the-art
  - Market analysis to guide R&D investments
  - Platform-based architecture and standards framework
  - Fundamental research in modeling and synthesis
- **Short Course for Executives delivered by world class industry and research leaders (January 19-20, 2012)**
- **R&D Needs Assessment Workshop: Foundations for Innovation in CPS (March 13-14, 2012)**
- **Performance Metrics for Intelligent Systems (PerMIS) Workshop – CPS Theme (March 20-22, 2012)**
- **Cyber-security for Cyber-Physical Systems Workshop (April 23-24)**
- **Planned CTO Roundtable (June 2012)**

Cybersecurity of CPS: New Challenges

- Need to address all the conventional aspects of cybersecurity, plus
- New issues and threats, e.g.
  - Complex software with non-deterministic behavior
  - Precise timing requirements
  - Cyber system as a threat vector for attack on the physical system rather than the object of attack