Foundations for Innovation in Cyber-Physical Systems

October 4, 2012
NSF workshop
on CPS

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U.S. Department of Commerce

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

Major Points

- CPS are critical to the nation's future
- Significant fundamental research is needed
- Serious measurements & standards barriers exist
- NIST has programmatic efforts underway

What are Cyber-Physical Systems?

- Integrated, hybrid networks of cyber and engineered physical elements
- Co-designed and co-engineered to create adaptive and predictive systems
- Enhance performance including safety and security, reliability, agility and stability, efficiency and sustainability, privacy

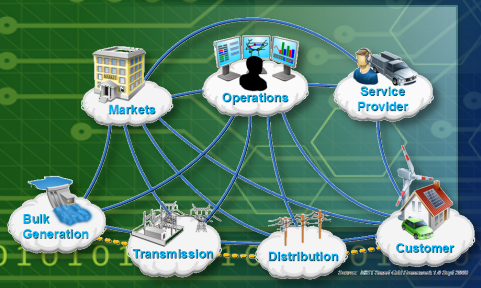
Reports Highlight CPS Significance

- **2011 PCAST Report *Ensuring American Leadership in Advanced Manufacturing*:** New methods and tools for engineering, testing and integrating CPS components
- **2010 PCAST Report *Designing a Digital Future*:** Increased research in areas that enhance interactions of networked cyber technologies with the physical world
- **2009 NITRD High-Confidence Medical Devices Report:** R&D focus on architectures, compositional modeling, and model-based design for advanced CPS medical devices
- **2007 PCAST Report *Leadership Under Challenge*:** New methods and tools to assure high levels of reliability, safety, security, and usability of CPS
- **2007 NRC Report *Software for Dependable Systems: Sufficient Evidence?*:** Agencies give high priority to IT R&D to enhance software-enabled system dependability

Cyber-Physical Systems -

Enabling a new generation of "smart" systems

Through the convergence of networking and information technology with manufactured products, engineered systems of products, and associated services



Buildings & Structures

Infrastructure

Emergency Response

SMART

Cyber-Physical Systems

Warfighting

Transportation

Healthcare

Smart Production

Many Federal Agencies Have a Common Stake in CPS R&D

- CPS linked to mission success
- CPS linked to innovation and economic growth
- Federal NITRD (Networking and IT R&D) program coordinates interagency CPS R&D

National Coordination Office for Networking and Information Technology Research and Development

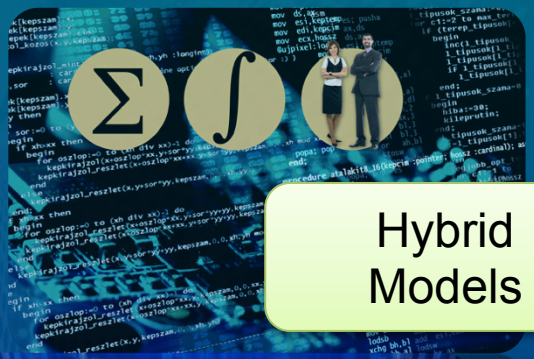
Potential Impacts

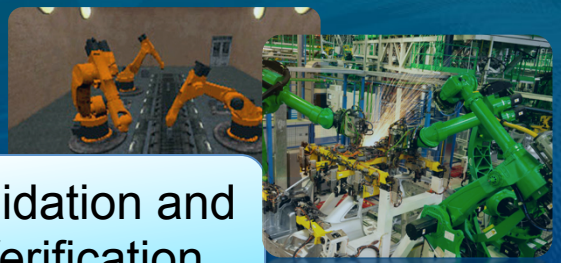
- Potential Economic Impact
  - Widespread disruptive technology
  - Innovative new products and services
  - Creation/retention of U.S. jobs

- Potential National Impacts
  - Strengthen U.S. security
  - Enhance U.S. competitiveness
  - Improve quality of life for Americans

Significant fundamental research is needed

Cyber-Physical Systems Concept Map





Hybrid Models

Wireless Sensing and Actuation

Validation and Verification

Control Systems

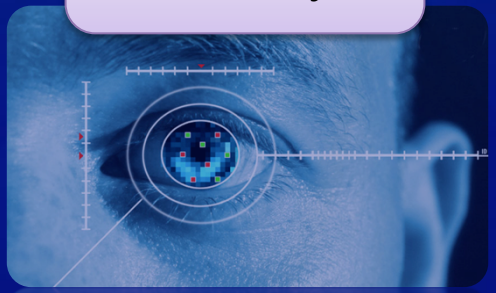
Cyber-Physical Systems

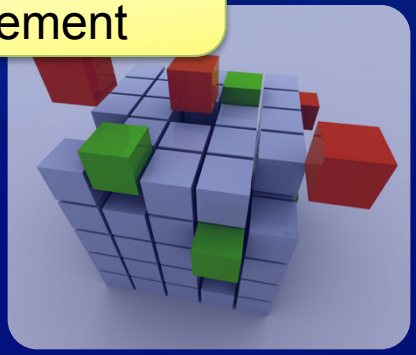
Applications of CPS

Concurrency, Communication, and Interoperability

Cyber Security

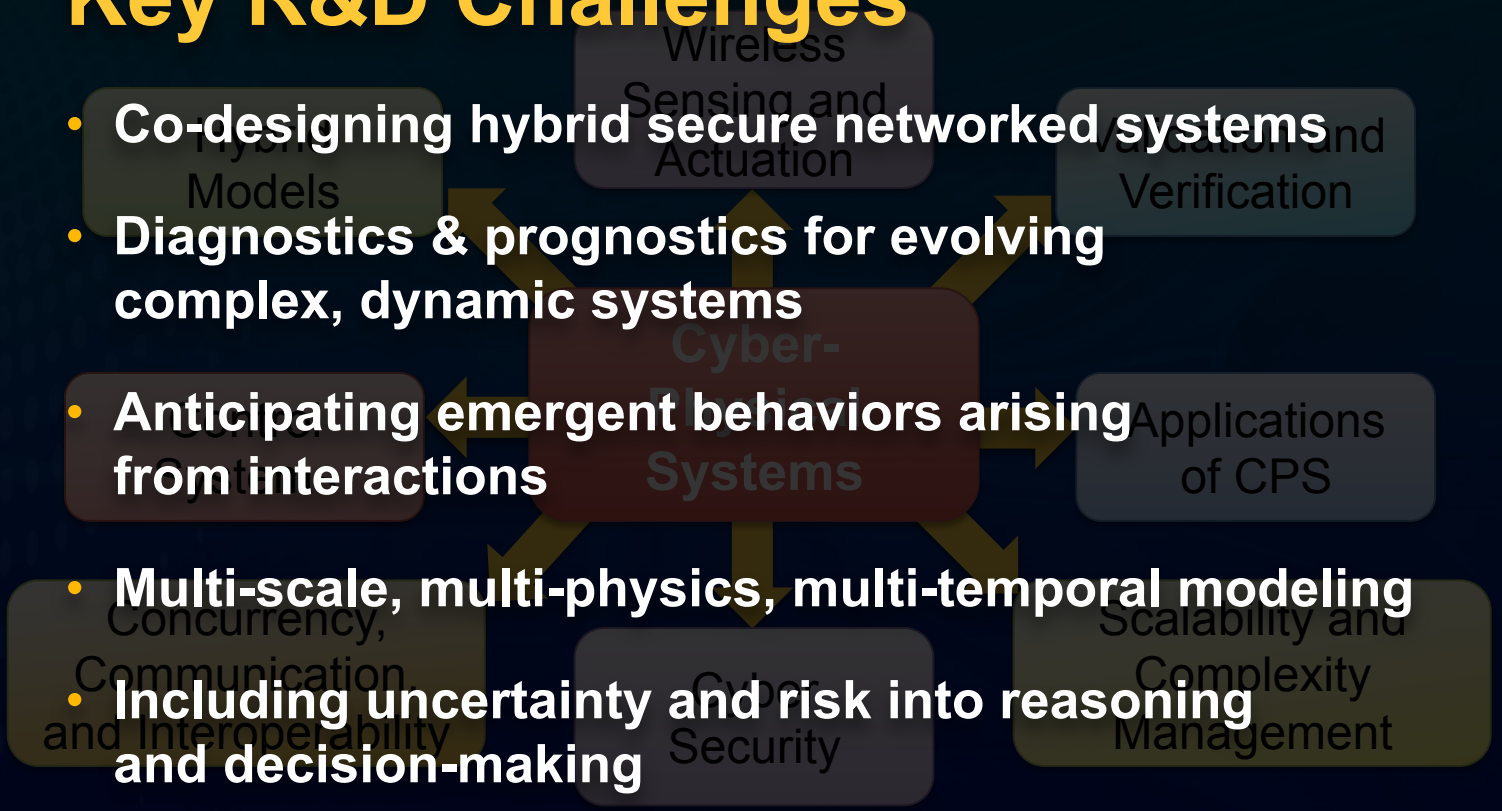
Scalability and Complexity Management





Source: Edward Lee, UC Berkeley http://cyberphysicalsystems.org

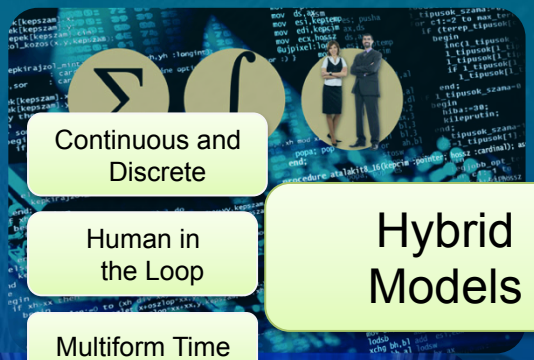
Key R&D Challenges



- **Co-designing hybrid secure networked systems**
- **Diagnostics & prognostics for evolving complex, dynamic systems**
- **Anticipating emergent behaviors arising from interactions**
- **Multi-scale, multi-physics, multi-temporal modeling**
- **Including uncertainty and risk into reasoning and decision-making**
- **Modeling levels of autonomy and optimizing the roles of humans**

Source: Edward Lee, UC Berkeley http://cyberphysicalsystems.org

CPS Platform Technologies: Concept Map



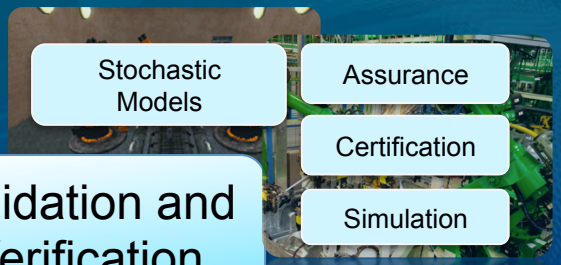
Continuous and Discrete

Human in the Loop

Multiform Time

Hybrid Models

Wireless Sensing and Actuation



Stochastic Models

Assurance

Certification

Simulation

Validation and Verification

Adaptive and Predictive

Networked Control

Intelligent Systems

Control Systems

Cyber-Physical Systems

Transportation

Warfighting

Infrastructure

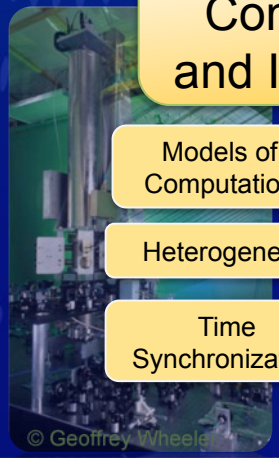
Healthcare

Manufacturing

Emergency Response

Applications of CPS

Concurrency, Communication, and Interoperability



Models of Computation

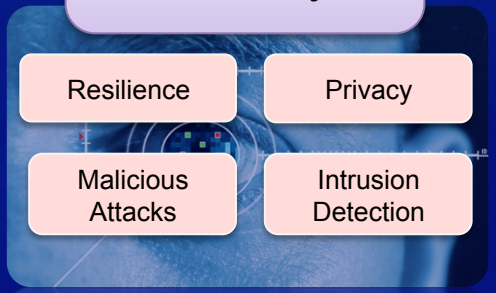
Heterogeneity

Time Synchronization

Real-Time Systems

Networking

Cyber Security



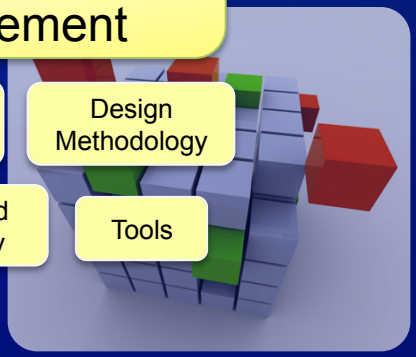
Resilience

Privacy

Malicious Attacks

Intrusion Detection

Scalability and Complexity Management



Legacy Systems

Modularity and Composability

Design Methodology

Tools

Source: Edward Lee, UC Berkeley http://cyberphysicalsystems.org

Serious measurement & standards barriers

What is NIST's CPS R&D portfolio?

- **Architectures**: Protocols for communications, control, cybersecurity, and interoperability
- **Models**: Validation, verification, uncertainty and integration
- **Sensors**: Calibration, uncertainties, wireless networks, robustness, interference
- **Cybersecurity**: Security of components and systems, protocol testing, graceful degradation

What is NIST's CPS R&D Strategy?

- Address cross-cutting measurements and standards challenges
- Enable self-consistent solutions across diverse applications
- Establish strong interagency and public-private partnerships

What has NIST done to date?

- NIST CPS Working Group (January 2011)
- Cooperative Agreement with University of Maryland for CPS R&D (Kick-off December 2011)
- Short Course for NIST Executives and Senor Staff delivered by world class industry and research leaders (January 19-20, 2012)
- Idea Submission Opportunity (crowdsourcing)
- 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 CPS Workshop (April 23-24, 2012)
- CTO Roundtable (June 18, 2012): Strategic Vision and Drivers
- CPS Testbed @ NIST

NIST has established a CPS Testbed

- Showcase NIST's measurement and standards research results
- Vehicle for implementing NIST's R&D strategy
- Integrate multiple application domains into a smart community

Smart Community

Summary

- CPS is critical for our future
- Significant fundamental research issues remain
- Serious measurements & standards barriers exist
- NIST has programmatic efforts underway

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