Foundations for Innovation in Cyber-Physical Systems

Advanced Manufacturing at NIST

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Visiting Committee on Advanced Technology, NIST

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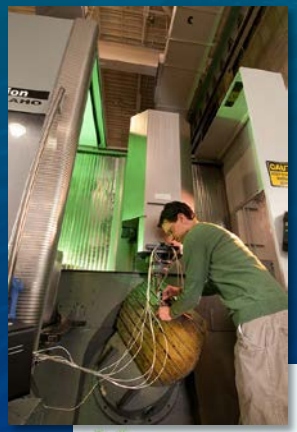
National Institute of Standards and Technology
U.S. Department of Commerce

Major Points

- **CPS** are the **FUTURE**
- Fundamental **R&D** is needed
- **NIST** is engaged **NOW**

Cyber-Physical Systems in the Context of Advanced Manufacturing

- Huge potential impact on manufacturing
- But, where are CPS standards?
- NIST has domain-specific programs
- Not addressing cross-cutting technology gaps
- Not addressing fundamental research challenges



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

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

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Buildings & Structures

Infrastructure

Emergency Response

Cyber-Physical Systems

Warfighting

Transportation

Healthcare

Smart Production

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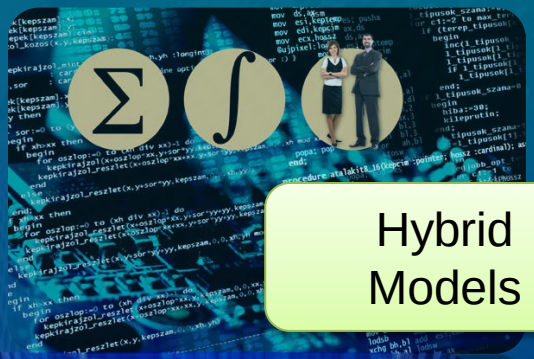
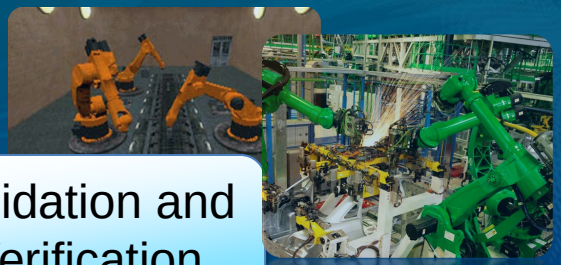
What are Cyber-Physical Systems?

- 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

Cyber-Physical Systems Concept Map





Hybrid Models

Wireless Sensing and Actuation

Validation and Verification

Control Systems

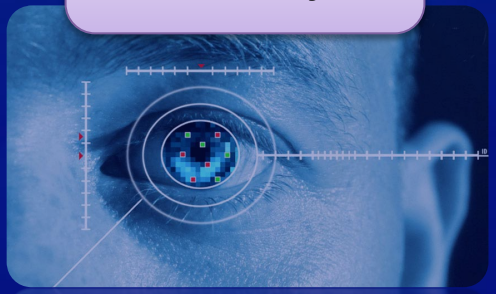
Cyber-Physical Systems

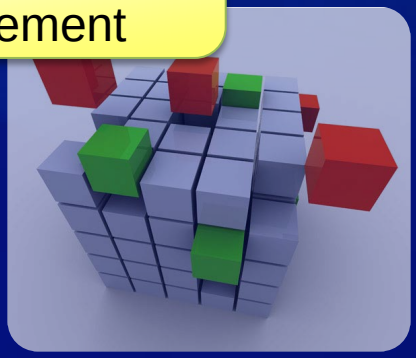
Applications of CPS

Concurrency, Communication, and Interoperability

Cyber Security

Scalability and Complexity Management





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

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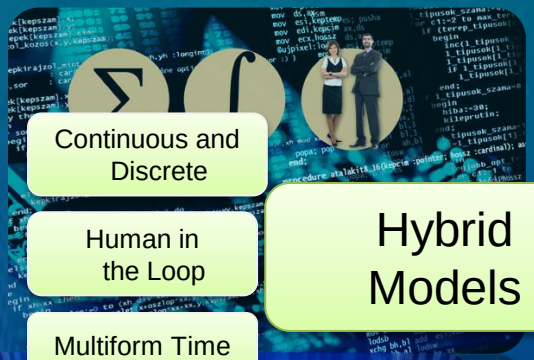
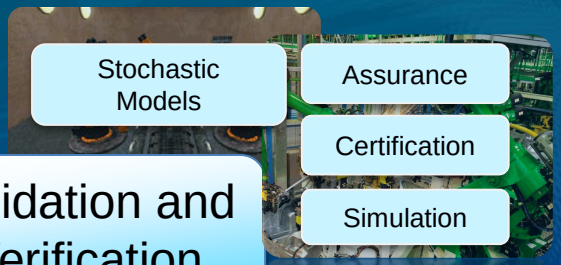
CPS Platform Technologies: Concept Map



- Continuous and Discrete
- Human in the Loop
- Multiform Time
- **Hybrid Models**

- **Wireless Sensing and Actuation**

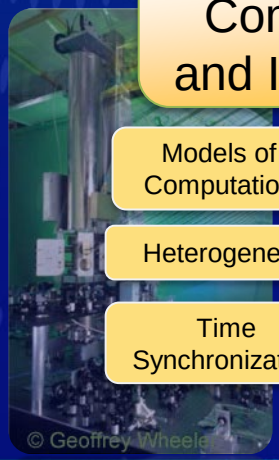


- Stochastic Models
- Assurance
- Certification
- Simulation
- **Validation and Verification**

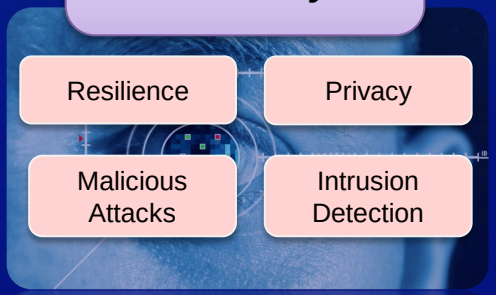
- Adaptive and Predictive
- Networked Control
- Intelligent Systems
- **Control Systems**

- **Cyber-Physical Systems**

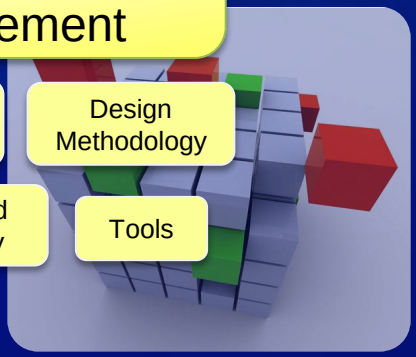
- Transportation
- Warfighting
- Infrastructure
- Healthcare
- Manufacturing
- Emergency Response
- **Applications of CPS**



- Models of Computation
- Heterogeneity
- Time Synchronization
- Real-Time Systems
- Networking
- **Concurrency, Communication, and Interoperability**



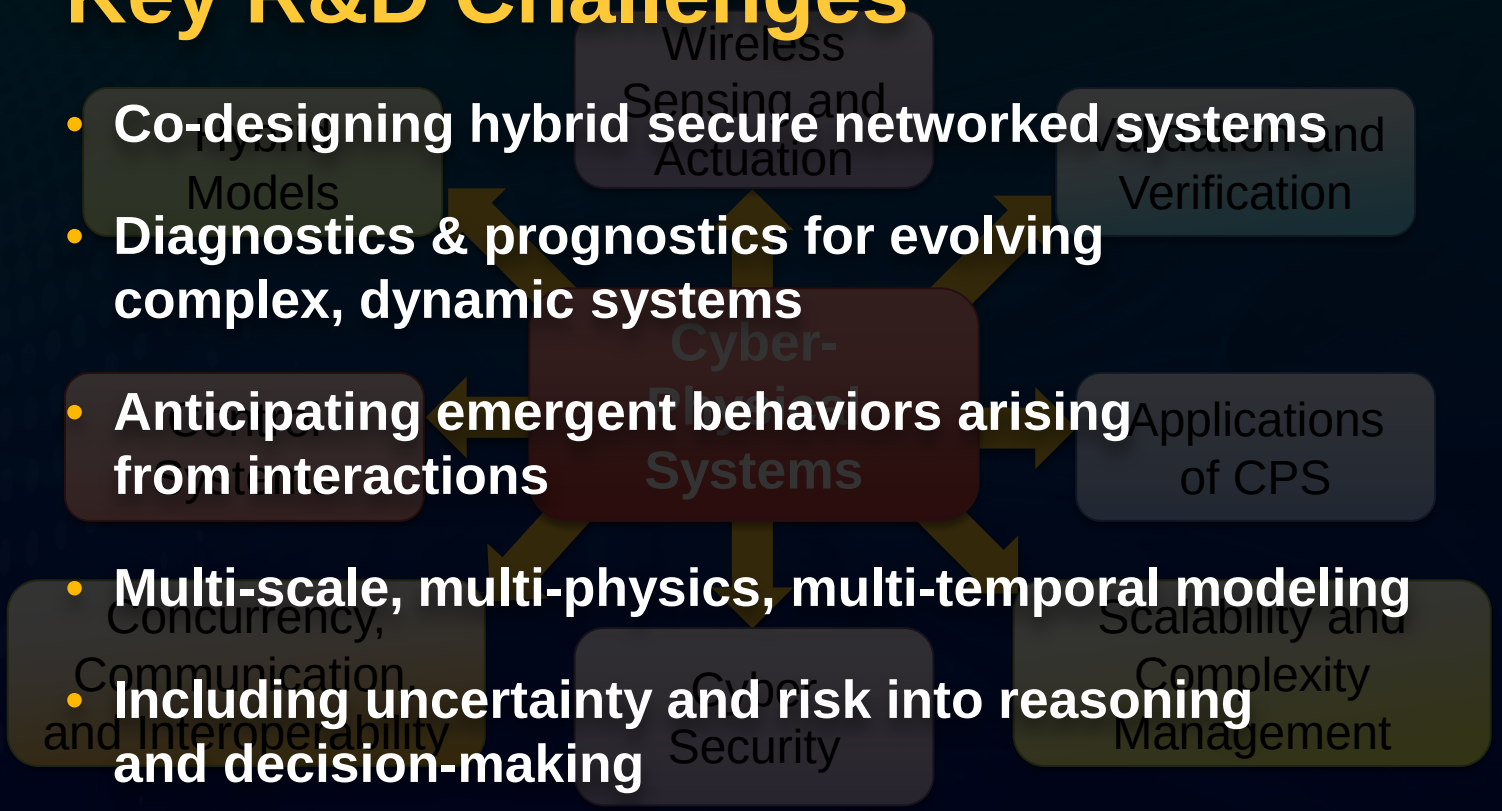
- Resilience
- Privacy
- Malicious Attacks
- Intrusion Detection
- **Cyber Security**



- Legacy Systems
- Design Methodology
- Modularity and Composability
- Tools
- **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

What is NIST's CPS R&D Strategy?

- Address cross-cutting R&D challenges through fundamental and applied research
- Enable self-consistent solutions across diverse applications through platform-based architectures, tools, and standards
- Establish strong interagency and public-private partnerships

Impacts

- Potential Economic Impact
  - Increased exports and reshoring
  - Innovative new products and services
  - Creation/retention of U.S. jobs

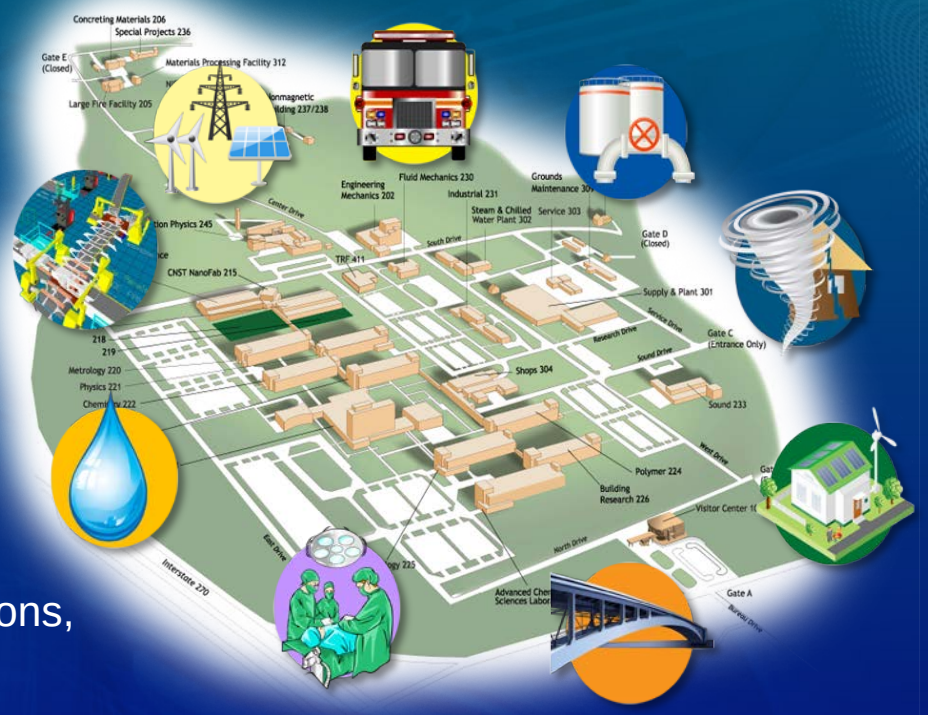
- Potential National Impacts
  - Strengthen U.S. economic and national security
  - Enhance U.S. competitiveness
  - Improve quality of life for Americans

NIST CPS Actions

- 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

CPS Testbed @ NIST

- NIST is developing a Cyber-Physical Systems testbed that will integrate multiple, distributed applications
  - Smart Manufacturing
  - Smart Micro-grid
  - Smart Structural Systems
  - Smart Fire Fighting
  - Smart Health Care



Smart Community

Testbed areas of study:

- **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

CPS in President's FY13 Budget Request to Support Smart Manufacturing (+$10M)

- Smart manufacturing exploits advances in numerous technologies to improve performance & quality at all levels
- CPS is a critical foundation for smart manufacturing

- Measurement Science and Standards for CPS Engineering
- Quality Measurement Systems for Smart Manufacturing

Summary

- CPS is critical for our future
- Significant fundamental research issues remain
- Numerous measurement science barriers exist
- NIST has programmatic efforts underway

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