Foundations for Innovation in Cyber-Physical Systems

Advanced Manufacturing at NIST

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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
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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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
- Control Systems
- Concurrency, Communication, and Interoperability
- Wireless Sensing and Actuation
- Cyber Security
- Applications of CPS
- Scalability and Complexity Management
- Validation and Verification

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

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CPS Platform Technologies: Concept Map

Cyber-Physical Systems

- Hybrid Models
  - Continuous and Discrete
  - Human in the Loop
  - Multiform Time
  - Adaptive and Predictive
  - Networked Control
  - Intelligent Systems

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

- Scalability and Complexity Management
  - Legacy Systems
  - Design Methodology
  - Modularity and Composability
  - Tools

- Wireless Sensing and Actuation
  - Stochastic Models
  - Assurance
  - Certification
  - Simulation

- Validation and Verification
  - Transportation
  - Intrusion Detection
  - Malicious Attacks

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

- Cyber Security
  - Resilience
  - Privacy

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 Senior Staff delivered by world class industry and research leaders (January 19-20, 2012)
• Idea Submission Opportunity (crowdsourcing)
• 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

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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