Cyber-Physical Systems

Workshop

on

Developing Dependable and Secure Automotive Cyber-Physical Systems from Components

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Troy, Michigan

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Overview

- Need
- What are Cyber-Physical Systems?
- CPS: An Interagency Agenda
- Pilot at the NSF: NSF FY09, FY10 CPS Competitions
- The CPS Virtual Organization: Building CPS Community

National Priorities and Challenges

- *Healthcare*
- *Energy*
- *Environment*
- *Economy: Sectors*
  - Manufacturing capacity, efficiency, agility
  - Energy and environmental technologies
  - Transportation: aviation, automotive, rail
    - Costs: automotive recalls, DC Metro, Airbus …
  - Biomedical and health technology

Is There a Problem to Be Solved?

- Example: automotive industry challenges, recalls
- Example: FDA Infusion Pump Initiative
- Example: Gulf of Mexico, other environmental disasters
- Loss of capacity for innovation
  - Shuttered factories
  - Decline in workforce capability, loss of skilled workforce
  - Education challenges
- Need for increased capability, resulting growth of system complexity

What are Cyber-Physical Systems?

What are Cyber-Physical Systems?

- Cyber – **computation, communication, and control** that are **discrete, logical, and switched**
- Physical – natural and human-made systems governed by the **laws of physics** and **operating in continuous time**
- Cyber-Physical Systems – systems in which the cyber and physical systems are tightly integrated at all scales and levels
  - Change from cyber merely appliquéd on physical
  - Change from physical with COTS "computing as parts" mindset
  - Change from ad hoc to grounded, assured development

"CPS will transform how we interact with the physical world just like the Internet transformed how we interact with one another."

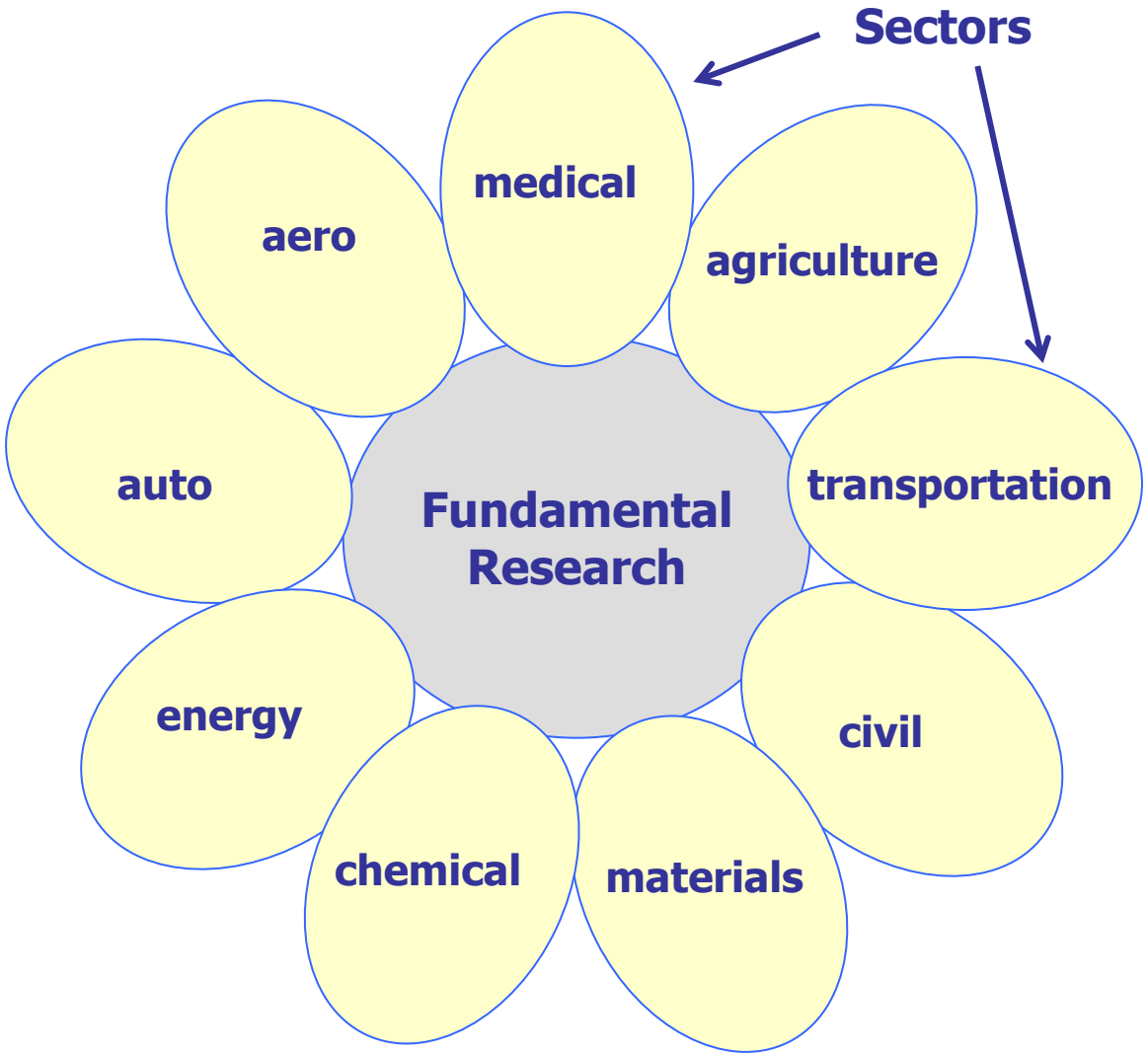
Characteristics of Cyber-Physical Systems

Some hallmark characteristics:

- Cyber capability in every physical component
- Networked at multiple and extreme scales
- Complex at multiple temporal and spatial scales
- Constituent elements are coupled logically and physically
- Dynamically reorganizing/reconfiguring; “open systems”
- High degrees of automation, control loops closed at many scales
- Unconventional computational & physical substrates (such as bio, nano, chem, …)
- **Operation must be dependable, certified in some cases**

Model for Expediting Progress*

- A new underlying discipline
- Abstracting from sectors to more general principles
- Apply these to problems in new sectors
- Build a new CPS community



* Jeannette M. Wing
Assistant Director, CISE, NSF

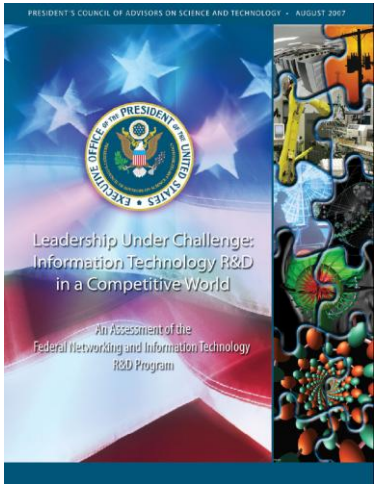
Not Just Business as Usual

- Not simply robotics/motion control/vision – rather, design for certifiably dependable control of (complex) systems
- Principles for bridging control, real-time systems, safety, security (not just a platform question – rather an interdisciplinary systems science issue)
- Next generation system architectures, a recurring question: "What's in a mode?" (cooperation/coordination? is the safety controller reachable?)
- Next generation system ID (bridging machine learning with traditional system ID state estimation, stochastics and uncertainty, purpose: reactive and predictive control)
- Next generation fault tolerance (not just TMR: multi-core/many-core, new forms of analytic and synthetic redundancy for FT, addressing interference and interaction, including separation/correlation reasoning)
- Next generation real-time systems (coordinated, dynamic multisystem scheduling; property-preserving scheduling; timed networks, precision timing)
- FPGAs and other reconfigurables; not just "software" – rather, next generation DA and PLs, system abstractions, software/system co-synthesis
- Safe AND Secure, Resilient AND Capable

CPS: An Interagency Agenda

CPS – A National Research Priority

- Eight priority areas for competitiveness, with four designated as having the highest priority
  - Network and Information Technology (NIT) Systems Connected with the Physical World
  - Software
  - Digital Data
  - Networking
- NIT systems connected with the physical world (cyber-physical systems)
  - Essential to the effective operation of U.S. defense and intelligence systems and critical infrastructures
  - At the core of human-scale structures and large-scale civilian applications



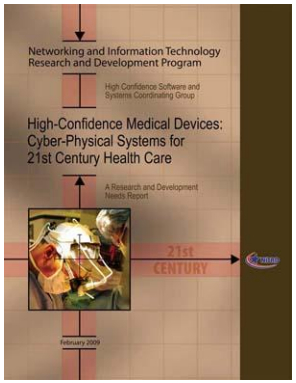
President's Council of Advisor's on Science and Technology (PCAST), Computational Science: America's Competitiveness Leadership Under Challenge: Information Technology R&D in a Competitive World, August 2007.

CPS: An Interagency Endeavor

Air Force Office of Scientific Research (AFOSR)
Air Force Research Laboratory (AFRL)
Advanced Research Projects Agency-Energy (ARPA-E)
Director, Defense Research and Engineering (DDR&E)
Department of Energy (DOE)
Department of Transportation (DOT)
Food and Drug Administration (FDA)
FAA-Joint Planning and Development Office (JPDO)
National Institutes of Health (NIH)
National Institute of Standards and Technology (NIST)
National Aviation and Space Administration (NASA)
Nuclear Regulatory Commission (NRC)
National Security Agency (NSA)
National Science Foundation (NSF)
National Transportation Safety Board (NTSB)
Office of Naval Research (ONR)

Each Workshop: Expected Outcome

- Report series on networking and information technology research needs, edited and published by the National Coordination Office (NCO) for Networking and IT R&D (NITRD)
  - High Confidence Medical Devices, Software, and Systems (published, 2008)
  - **Future Transportation CPS (editing underway)**
    - **>>THIS WORKSHOP <<**
  - **Future Energy CPS (editing underway)**
  - …



- Each report contains:
  - Community-based research needs assessment, product of one or more workshops
  - Government analysis of research needs for the area
- Interagency CPS Initiative workshop, March 2010
- CPS 2011 interagency white paper, penultimate draft

Pilot at the NSF

("If you build it, will they come?")

NSF FY09, FY10, FY11 CPS Competitions

Two year's experience

- Joint initiative:
  - Directorate for Computer and Information Science and Engineering (CISE)
  - Directorate for Engineering (ENG)
- Overwhelming response
- March 21, 2011 – proposals due

Program management

- Not merely a “grants” program
  - NSF 08-611, NSF10-515, NSF11-516 : PIs expected to participate in PI meetings
  - CPS Virtual Organization will enable coordination across projects and with industry, community-building
  - Future: possible incentives (e.g., supplements) to enable research teaming that spans projects, links to other entities
- Goal: sustained interactions outside of NSF
  - NITRD and US mission agencies
  - Industry/academia/government
  - Research communities
    - IEEE, ACM
    - CPS Week, ESWEEK, CDC, ACC, ICRA, CAV …
    - CRA and the Computing Community Consortium (CCC)
  - International research cooperation

The CPS Virtual Organization Building CPS Community

NSF Defined Objectives

- The objective of the CPS-VO is to actively build and support the multidisciplinary community needed to underpin this new research discipline and enable interagency and international collaboration on CPS.

- In support of the CPS-VO, Vanderbilt (PI: Christopher P. van Buskirk) will work with the community to develop strategies and mechanisms to facilitate:
  - *Community building*: interaction and exchange among CPS researchers across a broad range of institutions, programs and disciplines,
  - *Collaboration:* sharing knowledge, experimental tools, platforms and simulators
  - *Technology transfer and translational research:* information exchange between academy and industry, shared testbeds and industry defined scenarios
  - *International collaboration:* collaboration with international research groups, networks of excellence such as ARTISTDESIGN in Europe

Virtual Open Experimental Platforms

- NSF expects that Open Experimental Platforms (OEP) will be created by the CPS community. Examples for high impact platforms are Emulab (University of Utah), DETER (USC-ISI and UC Berkeley), C2 Wind Tunnel (Vanderbilt)
- The CPS-VO Repository will be prepared for hosting/integrating web accessible OEPs

Thank you!