Research Directions Collaboration in Cyber Physical Systems

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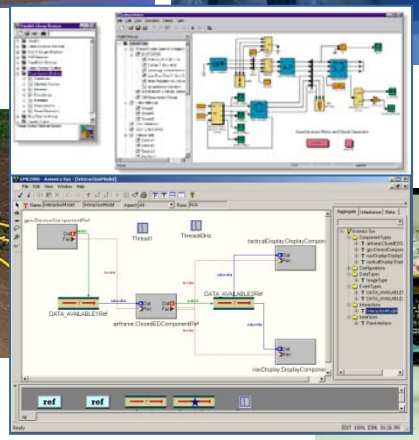
Outline

- Cyber-Physical Systems
  - NSF Vision and Approach
- Collaboration in CPS
- Concluding Remarks

Cyber Physical Systems

CPS are natural and engineered physical systems that are integrated, monitored and controlled by an intelligent computational core.



CPS Commonalities and Requirements

- Heterogeneous, deeply embedded into the physical world
  - Possibly distributed, deployed over extended areas, and mobile
- Fault-tolerant, reliable, robust, predictable, trustworthy and usable with high-confidence
- Scalable, rapidly configurable, adaptive, responsive and reactive
  - Possibly self-configuring and highly coordinated
- Affordable and cost-effective, user-friendly, efficient and long-lived

What's Particular About CPS?

- Major system's characteristics and functionality are defined by and the product of computational and physical interaction
- With tight integration of computational and physical, it becomes nearly difficult to identify what causes behavioral attributes
  - Computational, Physical or a Combination of both

Engineering Approach

- Cautiously over-design of systems with wide margins to achieve physical fa lt separation and i tion
- Tend to ignore i aspects of computing ar
  - Conside imple
- "Sepa often im architectu between the and physical
  - Severely limits abil to assess the impact and tradeoffs among a full range of design alternatives.

CS Approach

- Rely on rich abstractions to compose hierarchically designe ystems,
  - Abstra may lend thems dvanced ques, find subtle errors,

vior and ences in ems as "non-functiona rements.
  - Overly ifying assumptions are ma about the environment
    - Explicit representation of time, space, energy, temperature, and other aspects of the physical world.

Conjoint Design

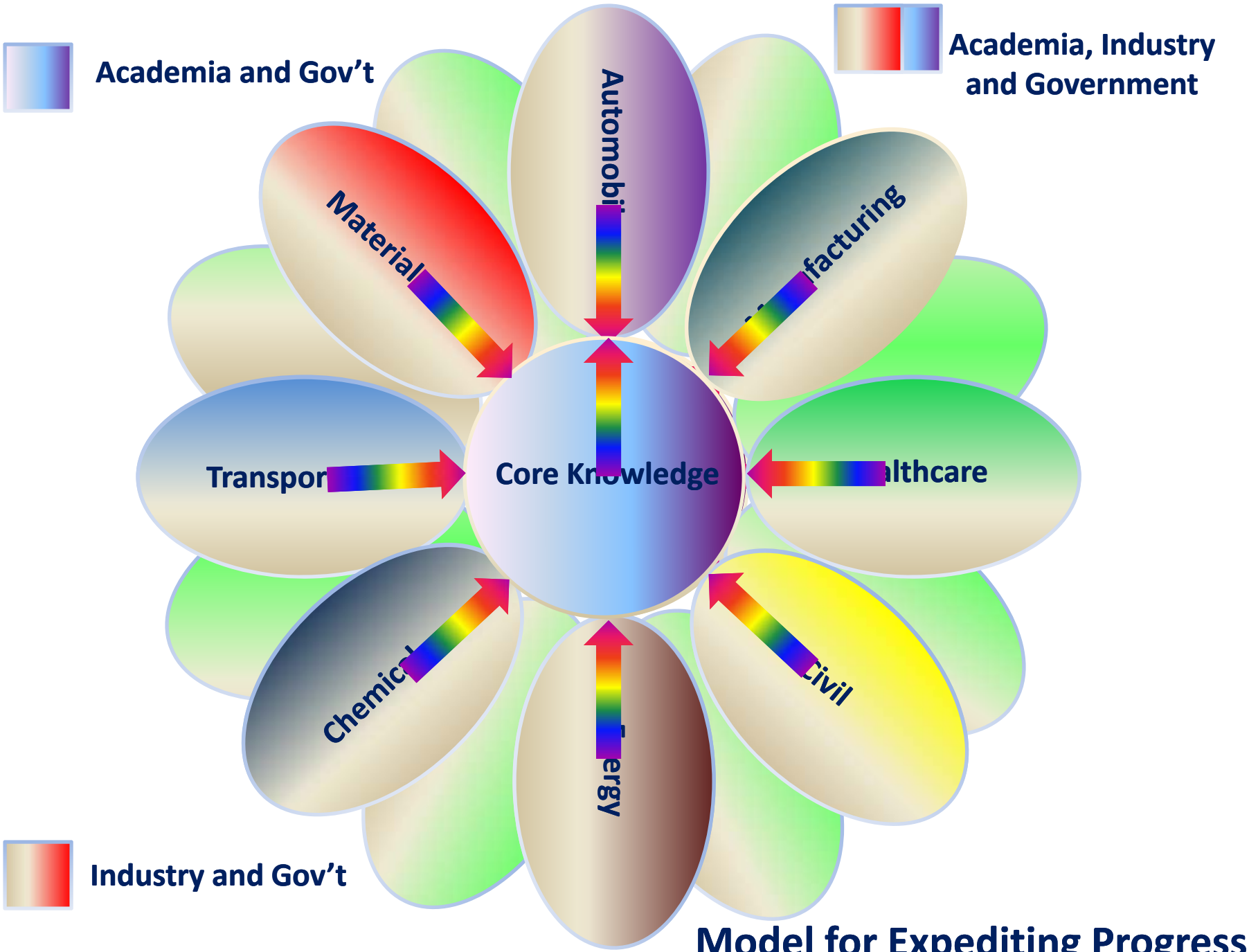
NSF Challenge!

- The trend in CPS is to rely less and less on human intervention and decision-making and more and more on the intelligence as embodied in the computational core.

How can we provide people and society with cyber-physical systems they can "bet their lives on"?

CPS@NSF

- "New CPS Science" requires the integration of knowledge and engineering principles across many computational and engineering research disciplines
  - Computing, networking, control, human interaction, learning theory, as well as electrical, mechanical, chemical, biomedical, nano-bioengineering, etc.
- Driven by existing and yet to be discovered application domains in many sectors,
  - Healthcare, bio-medical, transportation, automotive, aerospace, agriculture, national security, environment sustainability, energy, manufacturing and industrial automation.



Model for Expediting Progress

Potential Outcome

- Scientific foundations and engineering principles to conceptualize, design, analyze, implement certifiable CPS efficiently, reliably and safely
- Theories to accelerate and transform our ability to understand and exploit the interfaces between the cyber and physical worlds, including the ability to deal with complexity, timing, distribution, and uncertainty and the ability to modify behavior to adapt to variations in the environment.
- Feature-rich programming languages that capture the complex interactions between cyber and physical resources, including integration and interaction with human
- New techniques for assessing and exploiting the trade-offs in design alternatives that jointly consider the cyber and physical domains,
- Approaches to fully leverage the rapid advances in materials, devices, components and other technologies
- New context-aware abstractions, models and algorithms for real-time coordination, cooperation and autonomy at scale,
- New methods and tools that support multiple views of complex, integrated cyber and physical components, including capabilities to address the gap between the cyber and the physical and enable new forms of analysis, testing and validation of integrated discrete and continuous dynamics at multiple temporal and spatial scales and levels of abstraction

CPS Innovation through Global

- The multi-disciplinary nature of CPS research challenges highlights the need to rethink the way we manage innovation,
  - Research breakthroughs can no longer be best accomplished by a centralized and collocated research team
- Need for global collaborative strategies to stoke the pace of CPS innovation – Global Collaborative Competition to Foster Innovation
  - The aim is to establish mutually beneficial collaborative relationships
  - New collaborative frameworks to share and leverage peers' superior capabilities and "contextual" knowledge

Challenge is how to Build, organize and Sustain Collaboration!

Collaboration Challenges

- Lack of cross-national equivalence in term, concepts, theories, etc.
- Misconceptions and myths of researchers and funding agencies about international collaborations – it is often unclear how distant collaboration adds value to local work
- Differences between agencies' programmatic deadlines, time horizons, flexibility, funding mechanisms, project size, duration, etc.
- High coordination costs – projects will need to implement real coordination mechanisms and the budgets to support them

“Distance Matters”

- Difficult to establish mutual regard and common ground, increased misunderstanding[1]
- Delays in project schedule[2] and poor monitoring of progress[3]
- Information and awareness are distributed unevenly[4]

[1]Cramton, 2001, [2]Herbsleb et al., 2000, [3]Weisband 2001 and [4]Olson et al, 2001

Global collaboration – among scientists, engineers, educators, industry and governments – can speed the transformation of new knowledge into new products, processes and services, and in their wake produce new jobs, create wealth, and improve the standard of living and quality of life worldwide.

Arden L. Bement, Jr.
NSF Director
Cancun, Mexico
August 2005

NSF Cooperation Rules of the Road

- Investigator initiated international cooperation
- Every directorate and office invests in international activities
- Some have more bilateral agreements
- Others form global alliances of researchers or networked instruments

Rules of the Road (2)

- First Principle
  - Each country pays for its own researchers, EXCEPT
- Second Principle
  - If there is some special justification
  - If the work is in service to the US
    - Usually done through a sub-award

Issues with these Eligibility Rules

- Available funding depends on the whims or initiative of those currently in charge, no particular funds set aside
- Scientific officers in the US have to take initiative to find funds or value it highly in their own program; some are interested in international cooperation, others not; NSF program officers, management come and go
- Also, researchers must take initiative to find international partners, set up the research project, and then find willing programs at NSF and in the EC
- There are a lot of "ifs," which make the effort difficult to rationalize on the part of researchers

Items that are Eligible

- Supplements to existing awards
- Workshops, conferences
- International Travel
- New proposals
  - joint proposals, or single proposal with sub-award

CPS Virtual Organization

- Facilitate and foster interaction and exchanges among CPS researchers across a broad range of institutions, programs and disciplines,
- Enable dissemination and sharing of knowledge created by the broader CPS engineering and scientific communities,
  - Sharing and integrating of, experimental tools and platforms, simulators and other research outcome among researchers and stakeholders
- Facilitate and foster collaboration and information exchange between CPS researchers and industry and
- Foster international collaboration by facilitating the establishment of shared scientific terminologies, technical standards and testing methods.

Vanderbilt-ISIS will lead this effort to help achieve these community-wide objectives through a range of collaborative activities

Office of International Science & Engineering

- **Build excellence through international collaborative research and education activities.**
- **Broaden participation and engage more U.S. students and junior researchers through quality international experiences.**

Some NSF Funding Opportunities for International Cooperative Research and Education Activities:

- International Research Fellowship Program (IRFP)
- International Research Experiences for Students (IRES)
- Partnerships for International Research and Education (PIRE)

International Research Fellowship Program (IRFP), NSF 06-582

- Provide young scientists with international research opportunities for 9-24 months
- U.S. citizens/permanent residents with a PhD are eligible, but cannot have had a PhD longer than two years
- Applications from women and minorities, and for work in developing countries are especially encouraged.

http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5179&org=OISE&from=home

International Research Experiences for Students (IRES), NSF 04-036

- Faculty submits proposal for training graduate and/or undergraduate students
- Supports small groups of students for focused research experiences overseas
- $150,000 max ($50,000 per year for up to 3 years)

http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12831&org=OISE&from=home

Partnerships for International Research & Education (PIRE), NSF 09-505

- Research excellence via international collaboration
- Significant student training and outreach
- Strengthened international engagement by U.S. institutions
- Five year awards
- PIRE budget FY10-14: $40,000,000

http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12819

International Opportunities

Contact the NSF Office of
International Science and Engineering:
Bonnie H. Thompson
bhthomps@nsf.gov

Concluding Remarks

- Global collaboration is high risk endeavor
  - Engaging in a "serious" activity between disparate, and at times competitive, communities of scholars must be viewed as a high-risk investment of resources and times
- Success requires a sense of "community"
  - Confidence to build on the outstanding accomplishment record of the community
  - Open mindedness for new thinking and innovative ideas
  - Willingness to "do good" for the community
  - A sense of adventure
- Our "lives will depend on CPS"!

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Thank You!