Cyber-Physical Systems

CPS: The First Year

CPS Week 2020

EU-US Government Panel

April 13, 2010

Report: CPS – The First Year

- FY09 NSF CPS Solicitation and Strategy
- FY09 CPS Competition and Portfolio
- FY10 CPS and Other Funding Opportunities
- Conclusion

CPS Solicitation (NSF 08-611)

- Joint initiative of Directorate for Computer and Information Science and Engineering (CISE) and Directorate for Engineering (ENG)
- Proposals due February 27, 2009
- Total funding of up to about $30M, 30-40 awards
- Continuation in future years is expected

http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503286

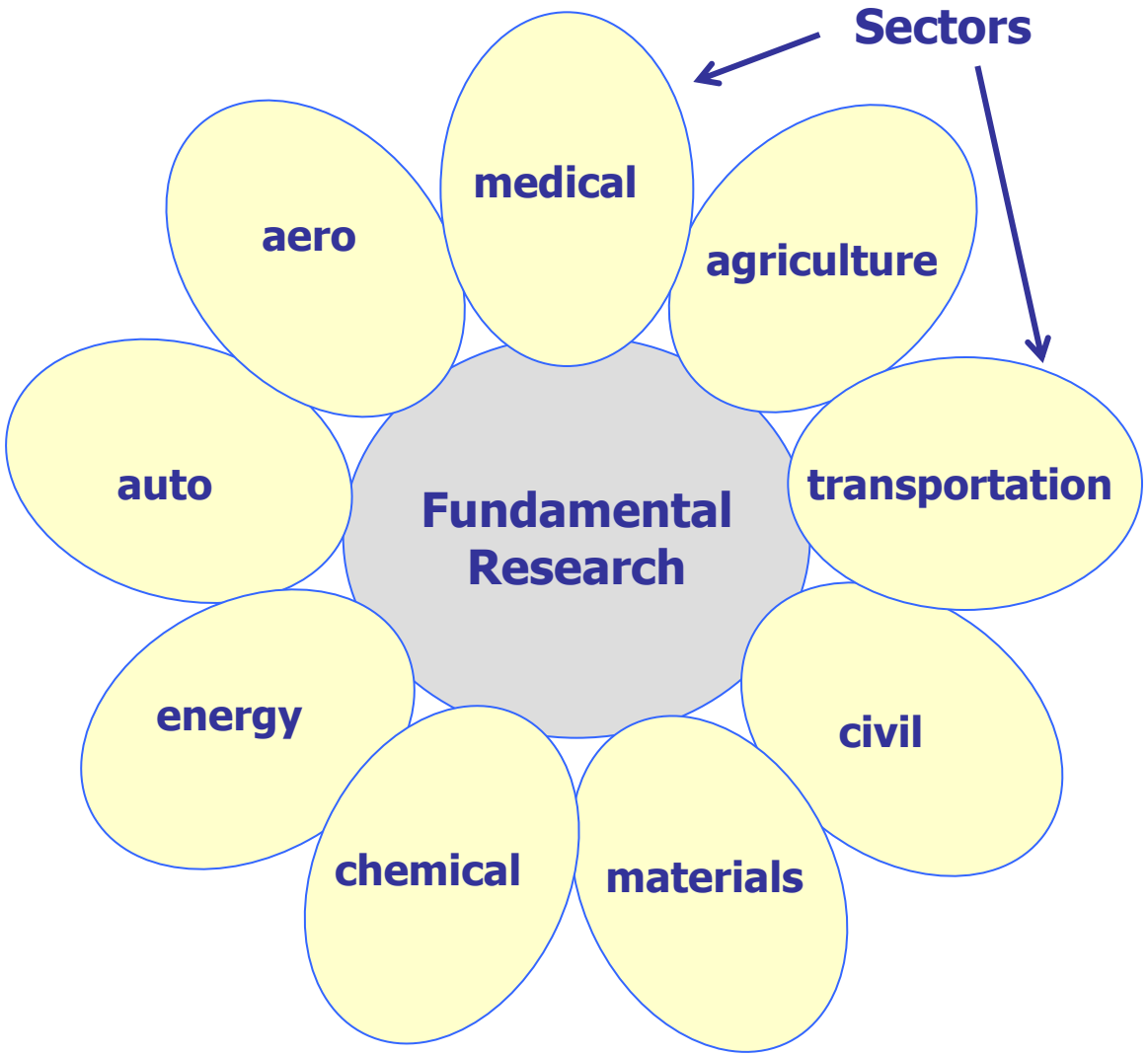
- FAQ
- Information Day and Community Workshop

What Science Gaps, Challenges?

- Current S&T is stove-piped. We need a spectrum of research (long-range, problem-driven, technology-driven) towards core CPS systems science, implementation technology, and engineering methodologies that:
  - Span distributed control, networking, autonomy, coordination, real-time response, human interaction, security, modeling, software, verification and assurance, …
  - Support joint cyber-physical engineering for controllable materials, devices, structures, physical processes, …
- The research transition pipeline stalls. We need a mix of problem-driven and idea-driven research, translational strategies, but with attention to capturing the common science, engineering principles
- We lack S&T for open, interoperable systems that deeply integrate the cyber and physical and produce predictable behavior
- A CPS educational strategy is needed to create the 21st century CPS workforce that will be required

NSF 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

Three CPS Themes

- *Foundations* – develop new scientific and engineering principles, algorithms, models, and theories for the analysis and design of cyber-physical systems
- *Research on Methods and Tools* – bridge the gaps between approaches to the cyber and physical elements of systems through innovations such as novel support for multiple views, new programming languages, and algorithms for reasoning about and formally verifying properties of complex integrations of cyber and physical resources
- *Components, Run-time Substrates, and Systems* – new hardware and software infrastructure and platforms and engineered systems motivated by grand challenge applications

Type of CPS Projects

- *Small Projects* – individual or small-team efforts that focus on one or more of the three defined CPS themes (up to $200,000/year for up to three years)
- *Medium Projects* – span one or more CPS themes and may include one or more PIs and a research team of students and/or post-docs (up to $500,000/year for up to three years)
- *Large Projects* – multi-investigator projects addressing a coherent set of research issues that cut across multiple themes or that explore a particular theme in great depth (up to $1,000,000/year for up to five years)
- *Virtual Organization* – facilitate and foster collaboration and information exchange (R2R, R2I)

Not Business as Usual

- Innovative research that spans the boundaries of engineering and computer science and their subdisciplines
- Balance and integrate both cyber and physical aspects
- Not
  - cyber merely appliquéd on physical
  - physical with COTS “computing as parts” mindset
  - recycled from a focused disciplinary research program
  - anecdotal case studies, but general CPS principles

Program management

- Not merely a “grants” program
  - NSF 08-611 (and NSF10-515) : 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
  - NSF CPS PD team will actively monitor and assess both individual projects and overall program progress
- Sustained interactions outside of NSF
  - NITRD and US mission agencies
  - Industry
  - Research communities
    - IEEE, ACM
    - CPS Week, ESWEEK, CDC, ACC, ICRA, CAV …
    - CRA and the Computing Community Consortium (CCC)
  - International research cooperation

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Overwhelming Response

642 Proposals !?!

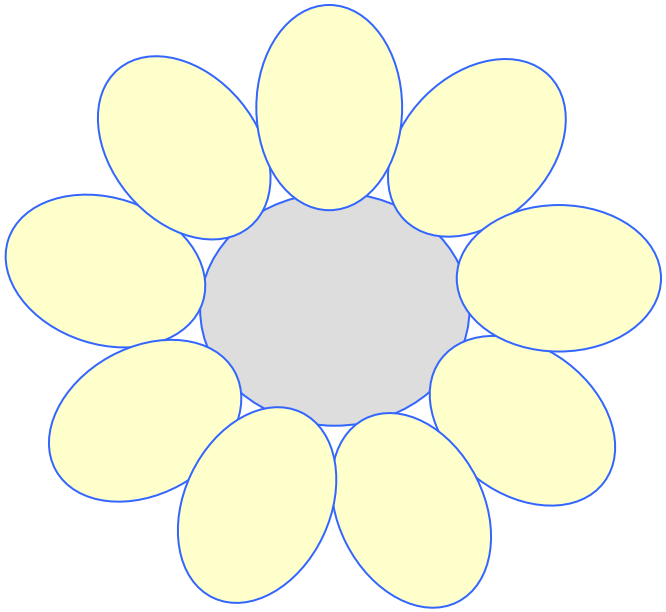
- **Real Opportunity/Problem**
  - PCAST, testimony, ARTEMIS
- **Pent Up Demand**
  - Workshops, Seed Programs (EHS), CPS Week
- **Outreach, Outreach, Outreach**
  - Dr. Jeannette Wing at Snowbird, CRA, …
  - CPS Week, ES Week, IROS, CDC, …
  - Info Day
- **Stimulus**
  - Pushed over the edge

Many helping hands … from A to Z

- Core CPS Team
  - Kishan Baheti, ENG/ECCS
  - Michael Branicky, CISE/CNS
  - Helen Gill, CISE/CNS
  - Scott Midkiff, ENG/ECCS
  - Paul Oh, CISE/IIS
  - Usha Varshney, ENG/ECCS
  - Lenore Zuck, CISE/CCF
- Staff (CISE/CNS)
  - Stephanie Elgersma
  - Cynthia Jackson
  - Chantini Reid
- Management
  - Ty Znati, CISE/CNS
  - Rajinder Khosla, CISE/CNS
  - Robert Trew, ENG/ECCS
  - Larry Goldberg, ENG/ECCS
  - Debbie Crawford, CISE
  - Jeannette Wing, CISE
- Special
  - Bruce Krogh
- Program Directors
  - Alhussein Abouzeid, CISE/CNS
  - Mitra Basu, CISE/CCF
  - Sankar Basu, CISE/CCF
  - Clark Cooper, ENG/CMMI
  - John Cozzens, CISE/CCF
  - Sajal Das, CISE/CNS
  - Ephraim Glinert, CISE/IIS
  - Deborah Jackson, ENG/EEC
  - Suhada Jayasuriya, ENG/CMMI
  - Krishna Kant, CISE/CNS
  - Dagmar Niebur, ENG/ECCS
  - Frank Olken, CISE/IIS
  - Rita Rodriguez, CISE/CNS
  - Sylvia Spengler, CISE/IIS
  - Jon Stoffel, OCI
  - Bill Tranter, CISE/CCF
  - Ken Whang, CISE/IIS
  - …

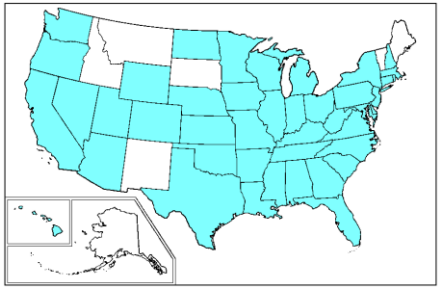
The whole community for peer review!

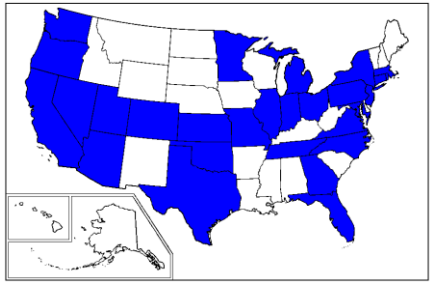
FY09 CPS Competition and Portfolio



NSF Baseline – CISE-ENG CPS Program FY09: By the Numbers

- 642 Proposals, totaling $580M in requests
- 527 CPS Projects, $45M in awards ($15.8M ARRA)
  - 248 Small → 30 funded (~12%)
  - 249 Medium → 26 funded (~10%)
  - 29 Large → 2 funded (~7%)

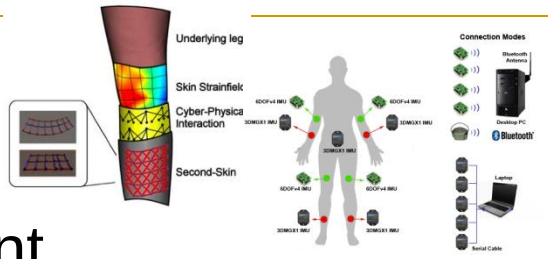


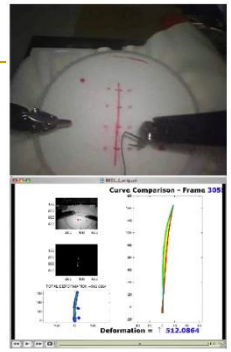


- CPS Virtual Organization Award: Vanderbilt University
  - CPS community-building and support: project portals, wikis, etc.
  - Support for experimental platforms, research results
  - PI meeting support, industry and interagency engagement

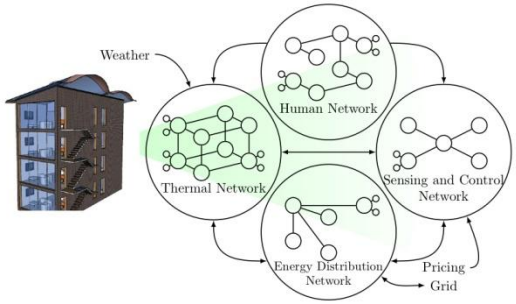
First Year (FY 2009) Awards

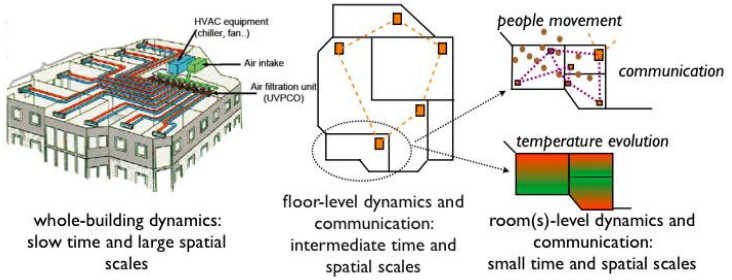
- Health and medicine



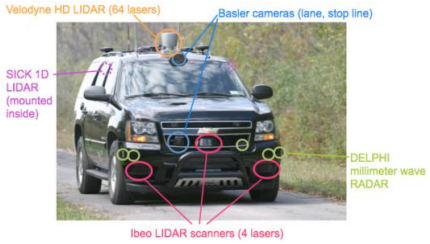


- Energy and environment

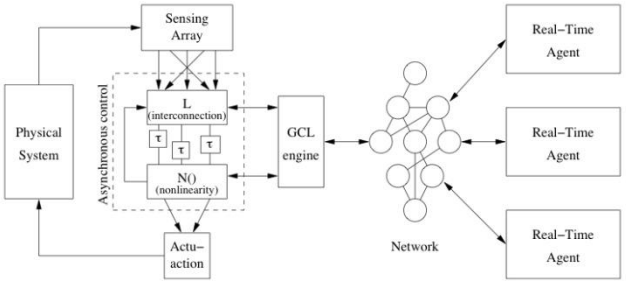


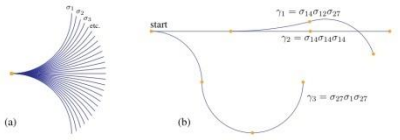


- Transportation (aviation and automotive)

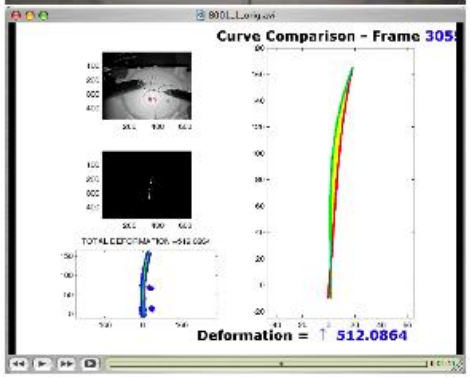


- New system science
- Platforms





Examples: Health and Medicine



- CPS:Medium:Hybrid Systems for Modeling and Teaching the Language of Surgery
  Gregory D Hager, Sanjeev P Khudanpur, Rajesh Kumar, Rene Vidal (JHU)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931805

- CPS:Medium:Image Guided Robot-Assisted Medical Interventions
  Nikolaos Tsekos, Zhigang Deng, Karolos M Grigoriadis, Ioannis A Kakadiaris, Javad Mohammadpour (U of Houston)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932272

- CPS Small: Control of Surgical Robots: Network Layer to Tissue Contact
  Blake Hannaford, Howard J Chizeck (U Washington)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0930930

- CPS:Medium:Collaborative Research: Infrastructure and Technology Innovations for Medical Device Coordination
  John Hatcliff, Dan Andresen, Robby, Steve Warren (KSU), Insup Lee, Oleg Sokolsky (U Pennsylvania)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932289

- Cybernetic interfaces for the restoration of human movement through functional electrical stimulation
  Eric Perreault (RIC, Northwestern), et al
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932263

- CPS:Medium: Programmable Second Skin to Re-educate Injured Nervous Systems
  Eugene C. Goldfield (Harvard Medical School, Children's Hospital Corp), Rob Wood and Radhika Nagpal (Harvard University), Dava Newman (MIT), Marc Weinberg (Draper), Kenneth Holt and Elliot Saltzman (BU)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932015

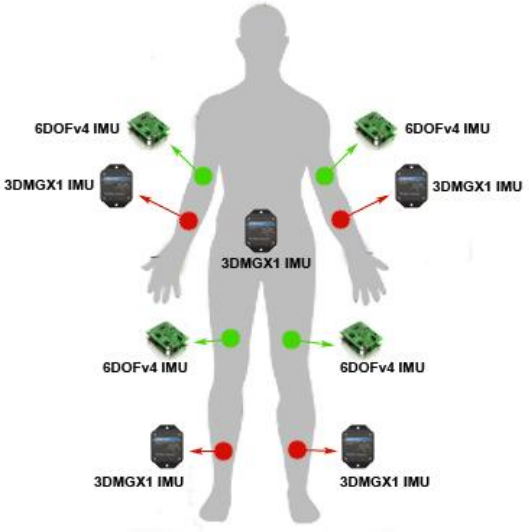
- CPS: Small: Cyber-physical system challenges in man-machine interfaces: context-dependent control of smart artificial hands through enhanced touch perception and mechatronic reflexes
  Veronica J Santos, Stephen I Helms Tillery (Arizona State U)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932389

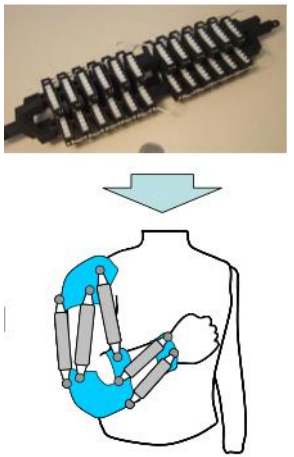
Examples: Health and Medicine (cont'd.)

- CPS: Medium: Collaborative Research: Monitoring Human Performance with Wearable Accelerometers
  Jessica Hodgins, Fernando de la Torre (CMU), Mark Redfern (U of Pittsburgh)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931999

- CPS: Medium: Active Heterogeneous Sensing for Fall Detection and Fall Risk Assessment
  Marjorie Skubic, Zhihai He, Dominic K Ho, James M Keller, Mihail Popescu (U Missouri)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931607

- CPS: Small: Collaborative Research: Foundations of Cyber-Physical Networks
  Jiawei Han (UIUC), John Stankovic (U Virginia)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931975





Examples: Energy and Environment

- CPS:Medium: LoCal - A Network Architecture for Localized Electrical Energy Reduction, Generation and Sharing
  Randy Katz, Eric A Brewer, David E Culler, Seth R Sanders (UC Berkeley)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932209

- CPS:MEDIUM:A Computing Framework for Distributed Decision Making to Ensure Robustness of Complex Man-Made Network Systems: The Case of the Electric Power Networks
  Rohit Negi, Franz Franchetti, Marija D Ilic, Ole Mengshoel (CMU)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931978

- CPS: Medium: Collaborative Research: GOALI: Methods for Network-Enabled Embedded Monitoring and Control for High-Performance Buildings
  Prabir Barooah (U. Florida), Alberto Speranzon (UTRC), Prashant Mehta and Sean Meyn (UIUC), Luca Carloni (Columbia)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931885

- GOALI/CPS:Medium:A Framework for Enabling Energy-Aware Smart Facilities
  Lucio Soibelman, H. Scott Matthews, Jose Moura (CMU), Burton Andrews and Diego Benitez (Bosch)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0930868

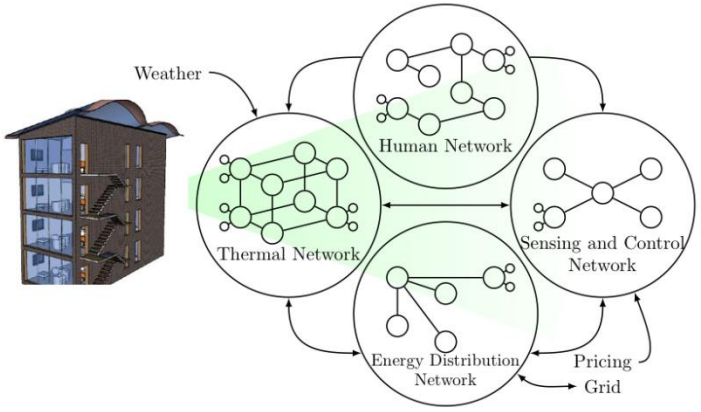
- CPS:Medium:Cyber-Enabled Efficient Energy Management of Structures (CEEMS)
  Tyrone Vincent, Robert Braun, Dinesh Mehta, Kevin Moore, Siddharth Suryanarayanan (Colorado School of Mines)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931748

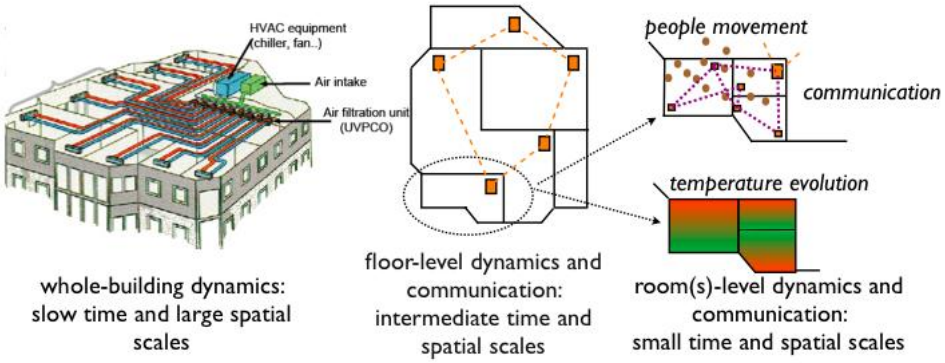
Examples: Energy and Environment (cont'd.)

- CPS: Small: Community-based Sense & Respond -- Theory and Applications
  Andreas Krause, K. Mani Chandy, Robert W Clayton, Thomas H Heaton (CalTech)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932392

- CPS:Medium:Collaborative Research: Physical Modeling and Software Synthesis for Self-Reconfigurable Sensors in River Environments
  Jonathan Sprinkle (U. Arizona), Sonia Martinez (UCSD), Alex Bayen (UC Berkeley)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0930919

- CPS: Small: Dynamically Managing the Real-time Fabric of a Wireless Sensor-Actuator Network
  Michael D Lemmon, Xiaobo Hu (Notre Dame U)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931195



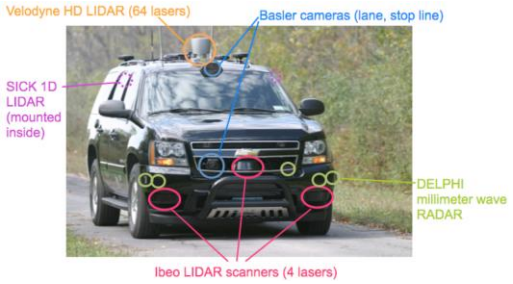


Examples: Aviation and Automotive Systems

- CPS:Large: ActionWebs
  Claire Tomlin, et al (UC Berkeley)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931843

- CPS: Medium: Collaborative Research: Abstraction of Cyber-Physical Interplays and Its Application to CPS Design
  Kang Shin and Ella Atkins (U. Mich), C. Mani Krishna and Israel Koren (U Massachusetts, Amherst)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0930813

- CPS:Medium: High Confidence Active Safety Control in Automotive Cyber-Physical Systems
  Francesco Borrelli, Ruzena Bajcsy, Karl Hedrick (UC Berkeley)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931437



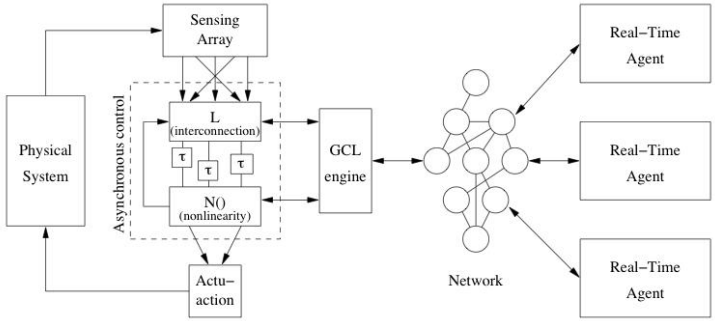
- CPS:Medium:Vehicular Cyber-Physical Systems
  Hari Balakrishnan, Samuel Madden, Daniela Rus (MIT)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931550

- CPS: Medium: Autonomous Driving in Mixed-Traffic Urban Environments
  Umit A Ozguner, Umit A Ozguner, Ashok K Krishnamurthy, Fusun Ozguner, Paolo A Sivilotti, Bruce W Weide (Ohio State U)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931669

- CPS:Medium: Tightly Integrated Perception and Planning in Intelligent Robotics
  Mark E Campbell, Daniel P Huttenlocher, Hadas Kress Gazit (Cornell)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931686

Examples: New Systems Science

- CPS:Large: ActionWebs
  Claire Tomlin, et al (UC Berkeley)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931843

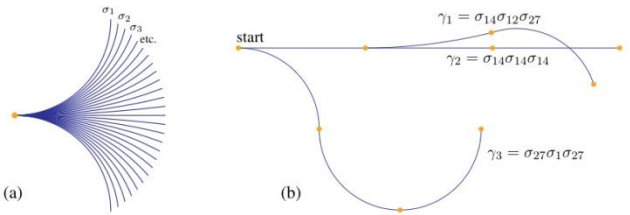


- CPS:Small:Control Design for CyberPhysical Systems Using Slow Computing
  Richard M Murray (CalTech)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931746

- CPS: Small: Compositionality and Reconfiguration for Distributed Hybrid Systems
  Andre Platzer, Edmund M Clarke (CMU)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931985

- CPS: Small: Collaborative Research: Establishing Integrity in Dynamic Networks of Cyber Physical Devices
  Vinod Ganapathy and Ulrich Kremer (Rutgers U), Trent Jaeger (Penn State U)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931992

- CPS: Small: Collaborative Research: Localization and System Services for SpatioTemporal Actions in Cyber-Physical Systems
  Rajesh Gupta (UCSD), Anish Arora (Ohio State U), Jay Bayne (Meta Command Systems, Inc.)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932360



Examples:
CPS Platforms and other Cool Things

- CPS: Small: RUI: CPS Foundations in Computation and Communication
  Mina Sartipi, Stephen D Craven (U Tennessee, Chatanooga)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932113

- CPS:Small: Non-Volatile Computing for Embedded Cyber-Physical Systems
  Gookwon E Suh, Edwin C Kan (Cornell U)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0932069

- CPS: Medium: Learning for Control of Synthetic and Cyborg Insects in Uncertain Dynamic Environments
  Pieter Abbeel, Ronald S Fearing, Michel M Maharbiz (UC Berkeley)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931463

- CPS: Small: Image Guided Autonomous Optical Manipulation of Cell Groups
  Satyandra K Gupta, Wolfgang Losert (U Maryland, College Park)
  http://www.nsf.gov/awardsearch/showAward.do?AwardNumber=0931508

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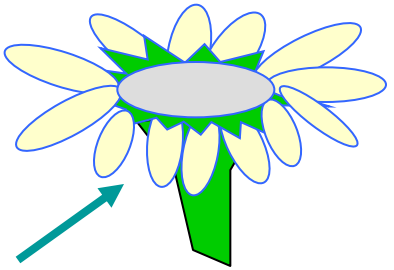
FY 2010 – CPS Second Year
CPS Solicitation (NSF 10-515)

- FY 2010 Solicitation:
  http://www.nsf.gov/pubs/2010/nsf10515/nsf10515.pdf
- Small changes for FY 2010
  - 2009 VO award in place, no subsequent VO competition
  - Minor clarifications
  - Proposal deadline: March 11, 2010

New CPS technology capabilities



- Total planned funding of up to about $30-34M, 30-40 awards
- No stimulus funds expected for FY 2010

Other Programs
Relevant to CPS and Embedded Computing

CISE Expeditions in Computing Program (EIC)

- http://www.nsf.gov/pubs/2008/nsf08568/nsf08568.pdf
- Funded at levels up to $2,000,000 per year for five years
  - 3-4 Awards/year
- EIC awards and program contact information:
  http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503169

  The Directorate for Computer and Information Science and Engineering (CISE) has created the Expeditions in Computing (Expeditions) program to provide the CISE research and education community with the opportunity to pursue ambitious, fundamental research agendas that promise to define the future of computing and information. In planning Expeditions, institutions to combine their creative talents in the identification of compelling, transformative research agendas that promise disruptive innovations in computing and information for many years to come.
- CMACS: Computational Modeling and Analysis for Complex Systems,
  - Carnegie Mellon University, City University of New York, New York University, Stony Brook University, University of Maryland, Cornell University, Jet Propulsion Laboratory, and University of Pittsburgh
  - http://cmacs.cs.cmu.edu/

NSF Partnerships for International Research and Education (PIRE)

- The Partnerships for International Research and Education (PIRE) program seeks to catalyze a higher level of international engagement in the U.S. science and engineering community by supporting innovative, international research and education collaborations. The program will enable U.S. scientists and engineers to establish collaborative relationships with international colleagues in order to advance new knowledge and discoveries at the frontiers of science and engineering and to promote the development of a diverse, globally-engaged U.S. scientific and engineering workforce.

- *The PIRE program has been run on a 2-year cycle and so will not be accepting proposals during FY2010. OISE hopes to release a new PIRE solicitation in the second half of 2010, with proposals due sometime in FY2011. Any changes in the status of a new PIRE solicitation will be announced on this PIRE webpage, so please check back during the late summer or fall of 2010.*

- PIRE awards and program contact information: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12819

Report: CPS – The First Year

- FY09 NSF CPS Solicitation and Strategy
- FY09 CPS Competition and Portfolio
- FY10 CPS and Other Funding Opportunities
- Conclusion

Conclusion

- Exciting, challenging year – many interesting, consequential projects, and a highly promising future
- Important tasks lie ahead for the CPS Community:
  - Community-building, joint efforts
  - Work at the disciplinary intersections
  - Expanding involvement of engineering, physical disciplines
  - Creation, curation, management of contributions to core CPS science and technology
- Congratulations on major new achievements: CPS Week now international, LCTES, and ICCPS

Thank you