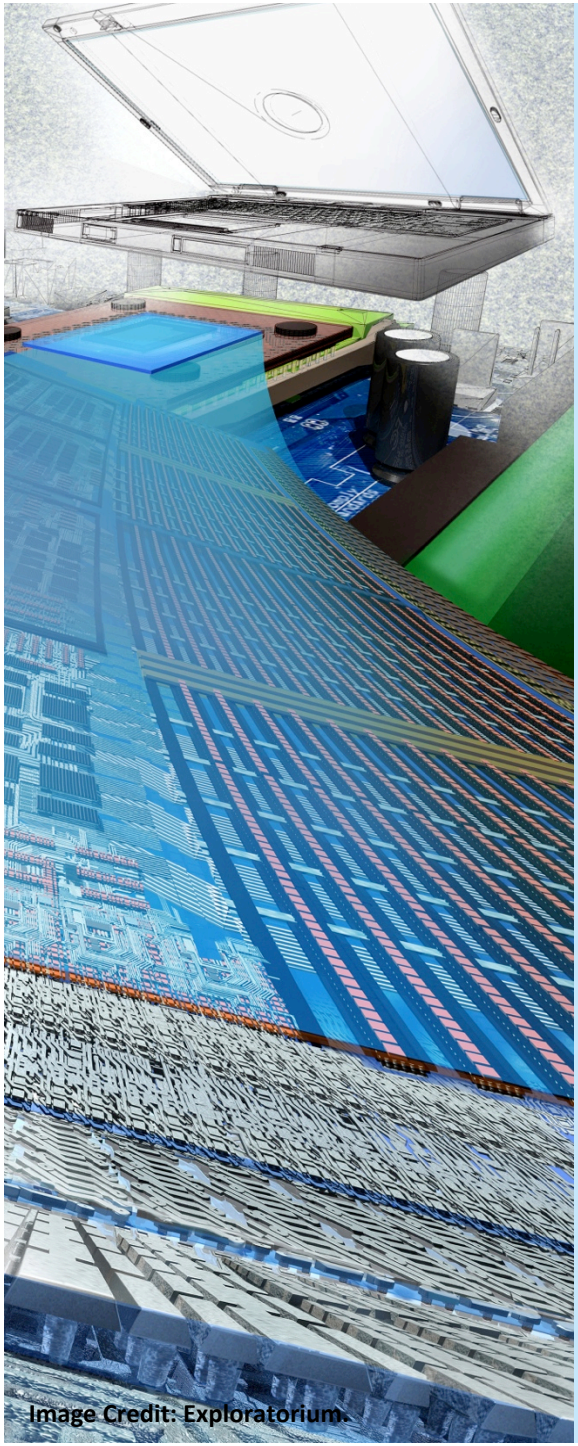



# *Cyber-Physical Systems Program*

**Keith Marzullo**
**Division of Computer and Network Systems**
**CISE Directorate**
**National Science Foundation**

# Goals of CPS program

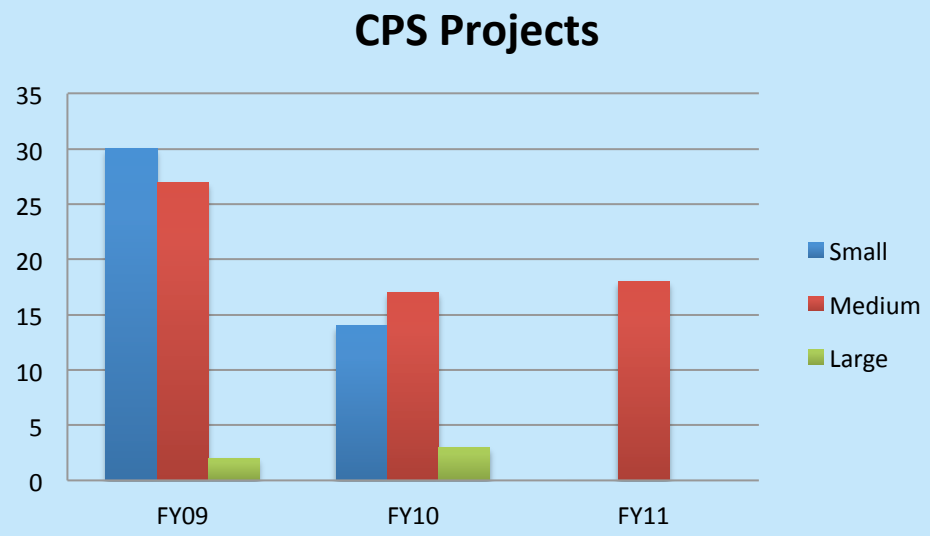
- **Establish a scientific basis for CPS**: unified foundations, models, tools, and principles
- **Synthesize knowledge** from disciplines that interface the cyber and physical worlds to model and simulate complex systems and dynamics
- **Enable usability, adoption, and deployment of complex systems** through fundamental cognitive, behavioral, economic, social, and decision sciences
- **Design for reliable, robust, safe, scalable, secure, and certifiably dependable control of complex systems** – CPS people can bet their lives on
    - Support networked, cyber-physical systems with built-in assurance, safety, security, and predictable performance
- **Develop, document, and disseminate research-based standards and best practices for CPS**
- **Advance cyber-enabled discovery and innovation** to enhance understanding and management of complex systems
- **Prepare the next generation of talent** for CPS through education and workforce development

Enable a research community and workforce that will be prepared to address the challenges of next generation systems

Bridge previously separated areas of research to develop a unified systems science for cyber-physical systems

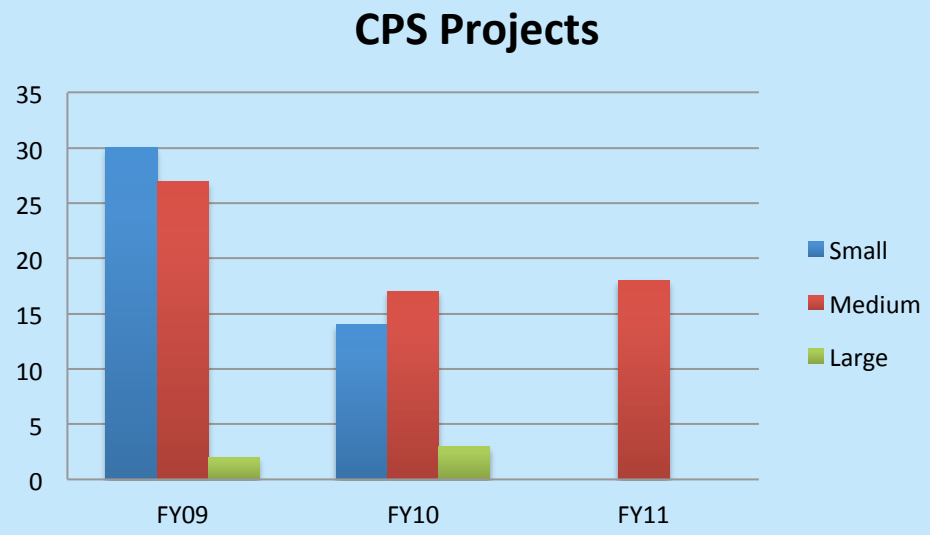
Develop new educational strategies for a 21st century CPS workforce that is conversant in both cyber and physical aspects of systems

# Number of funded projects




Small: $200K/Y for up to 3Y
Medium: $500/Y for up to 3Y (4Y)
Large: $1M/Y for up to 5Y

# Number of funded projects

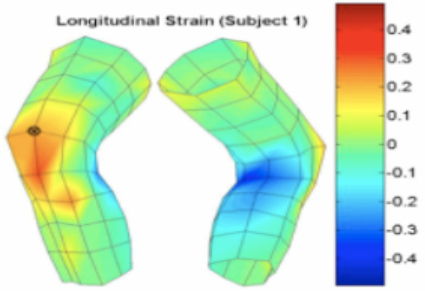


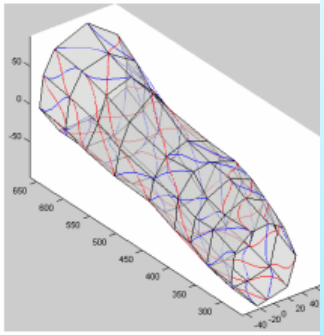

Small: $200K/Y for up to 3Y
Medium: $500/Y for up to 3Y (4Y)
Large: $1M/Y for up to 5Y

**FY12**
Breakthrough: $750K for up to 3Y
Synergy: $750K-$2M for up to 4Y
Frontier: $1.2M-$10M for up to 5Y

# Some CPS Awards

**Assistive Medical Technologies:** Programmable second skin senses and re-educates injured nervous systems. (Eugene Goldfield, Harvard Medical School)



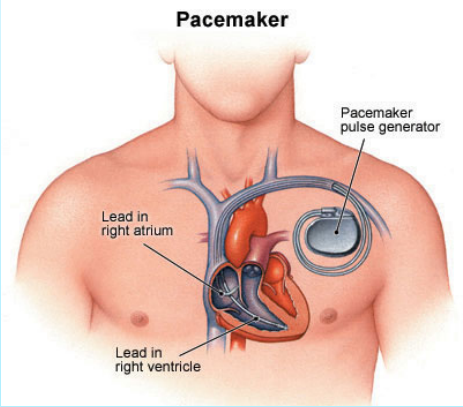
Credit: Wyss Institute, Harvard University

**Environmental Sensing**: Modeling and software allow actuated sensing in dynamic environments, such as rivers. (Jonathan Sprinkle, U. Arizona; Sonia Martinez, UCSD; Alex Bayen, UC Berkeley)


**Autonomous Vehicles**: Development of precision and real-time sensors, smart algorithms, and verification tools enables self-driving cars. (Ragunathan "Raj" Rajkumar, CMU, et al.)

# Some CPS Awards

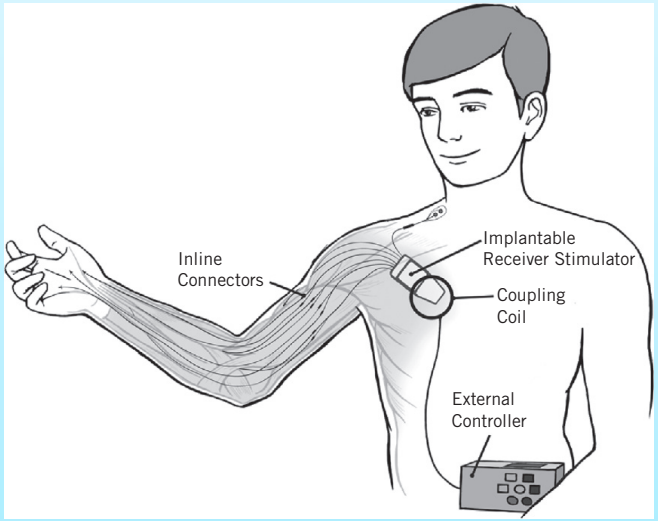
**Assistive Medical Technologies:** establish a new development paradigm that enables the effective design, implementation, and certification of medical device cyber-physical systems. (Insup Lee, U. Penn)



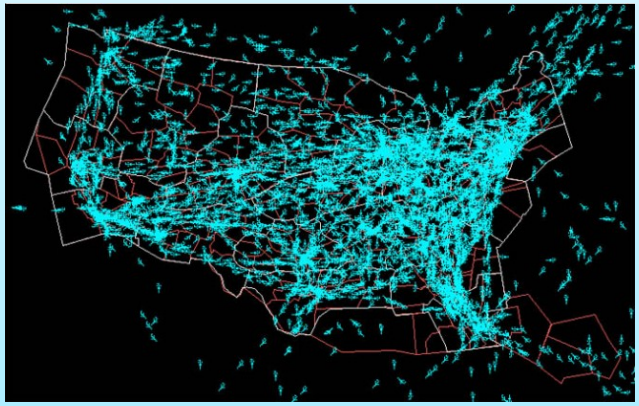

**Citizen Sensing**: What is the ideal structure of systems that detect critical events - such as earthquakes - by using data from large numbers of sensors held and managed by ordinary people in the community?. (Andreas Krause, et al., CalTech)

# Some CPS Awards

**Assistive Medical Technology**: develop an intuitive user interface for functional electrical stimulation which uses surgically-implanted electrodes to stimulate muscles in spinal cord-injured patients. (Eric Perreault, Rehabilitation Institute of Chicago)




**Critical infrastructure**: develop a theory of *ActionWebs*: networked embedded sensor-rich systems, which are taskable for coordination of multiple decision-makers. (Claire Tomlin, Ed Lee, Shankar Sastry, David Culler and Hamsa Balakrishnan, UC Berkeley)



**CPS Integration**: develop new foundations of composition in heterogeneous systems; apply foundations in a new generation of tools for system integration; validate the results in experiments using automotive and avionics System-of-Systems experimental platforms. (Janos Sztipanovits, Vanderbilt)

System integration is the elephant in the CPS china shop

# Major Changes: NSF 12-520

**IMPORTANT INFORMATION AND REVISION NOTES**

- The Cyber-Physical Systems program solicitation has been revised extensively for the FY 2012 competition. You are advised to read the solicitation carefully, as many aspects have changed. Among the significant changes, the following are worthy of special notice:
- **Greater emphasis is placed on developing the fundamentals of CPS, focusing on science, technology and engineering concepts that apply across more than one CPS application domain.**
- **The goals and expectations of the program have been re-articulated with a view toward emphasizing the importance of building bridges across traditional discipline boundaries.**
- **The previous CPS "themes" have been replaced by CPS Research Target Areas: Science of Cyber-Physical Systems, Technology for Cyber-Physical Systems, and Engineering of Cyber-Physical Systems.**
- The two proposal types (Medium and Large) have been replaced by three new types (Breakthrough, Synergy, and Frontiers), with descriptions intended to emphasize differences in the characteristics of the expected research goals for each type rather than size of budget.
- The ranges of funding levels for the Synergy and Frontier types of proposals overlap.
- Multi-institutional Collaborative Research proposals are allowed for all proposal types.
- Each type of proposal has significantly different requirements, for both technical content and proposal preparation instructions.
- Breakthrough proposals have specific requirements for the Project Summary.
- Frontiers proposals have additional requirements for Supplementary Documents.

# Three CPS Research Target Areas

- **Science** of Cyber-Physical Systems:

  The classical models of computation and physics are separately inadequate to capture the semantics of CPS. CPS require new models and theories that unify perspectives, capable of expressing the interacting dynamics of the computational and physical components of a system in a dynamic environment. A unified science would support composition, bridge the computational versus physical notions of time and space, cope with uncertainty, and enable cyber-physical systems to interoperate and evolve.

- **Technology** for Cyber-Physical Systems:

  New design, analysis, and verification tools are needed that embody the scientific principles of CPS, and that incorporate measurement, dynamics, and control. The tools should offer important perspectives into behaviors and interactions. New building blocks are also needed, including hardware computing platforms, operating systems, and middleware. The chain of tools and building blocks must integrate to support end-to-end assurances, and cover the full lifecycle of systems. Particular attention should be given to interfaces, interface management, extensibility, interoperability, and the controlled visibility of explicit and implicit assumptions. A particular goal is to enable evidence-based certification, and maintain certification as a system evolves.

# Three CPS Research Target Areas

- **Engineering** of Cyber-Physical Systems:

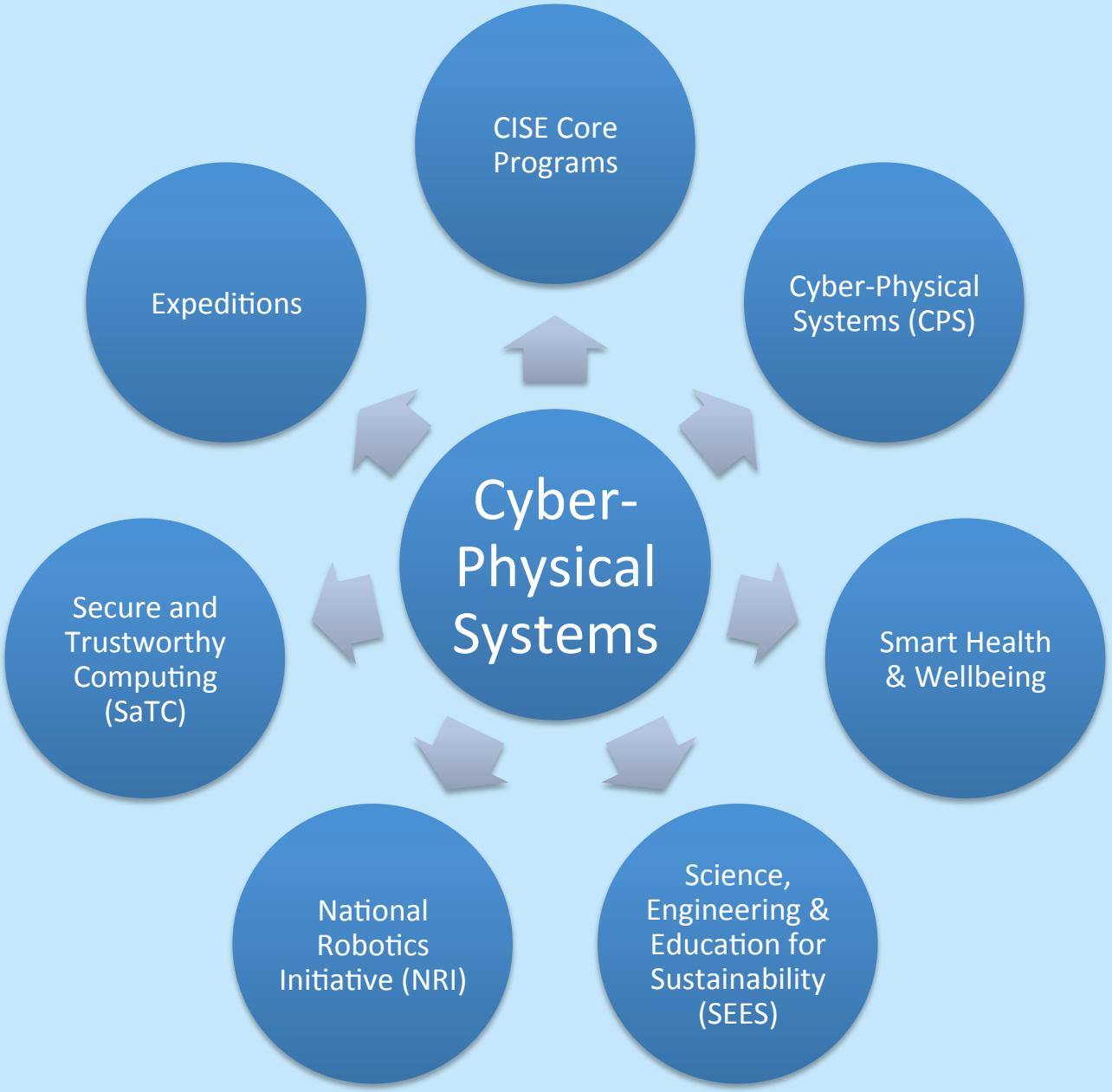
  CPS opens a new opportunity to rethink principles of systems engineering, built on the foundation of CPS science and technology and able to support open cyber-physical systems. Attention should be given to system architecture, design, integration, and design space exploration that produce certifiably dependable systems. New engineering principles are needed to systematize design for the growing numbers of CPS that entail adaptation and autonomy. All advances should be assessed and validated for relevance, usability, and effectiveness by appropriate benchmarks. The engineering processes must support certification and maintenance of certification over the system lifecycle.

## NSF 12-520: (cont'd)

# Other Requirements

- **Challenge Applications:** The program welcomes projects that explore ***next-generation CPS applications in conjunction with research*** in one or more of the three CPS Research Target Areas. Such projects should contribute to engineering innovation and incorporate careful experimentation designed to inform CPS science and technology. Systems of interest will be at the same time transformative and translational, demonstrating inventive new ideas and multi-disciplinary technical approaches to societal challenges. Challenge applications can range from extremely focused inventions enabled by CPS technology to revolutionary approaches to next-generation infrastructures. The CPS program encourages projects that address concerns shared with other federal agencies
- **Experimentation in CPS Projects:** ***Principled experimentation***, prototyping, and validation are expected for all CPS projects, and required for projects of greater than three (3) years. Experimentation that involves humans or animals, whether directly as in medical research or indirectly in cyberspace, must be in accordance with ethical guidelines and approved by the organization's Institutional Review Board. Active engagement with industry and other academic institutions is strongly encouraged; any such unfunded collaboration should be documented by letters of commitment.

# CPS Support across NSF



***Thank you!***

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